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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative in December 1947.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects. It is intended that the Society should be representative of the profession. Those not engaged in the practice of forestry or the allied sciences are cordially invited to join as Ordinary Members.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in May and November. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

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[*continued on inside back cover*

PLATE I

THE WORK OF F.A.O.

By H. BERESFORD-PEIRSE

NEITHER its name—the Food and Agriculture Organization of the United Nations—nor its motto—*Fiat panis*—shows that F.A.O. has a forestry role assigned to it. Yet it is logical that it should have, for F.A.O. is one, and in fact the first, of the 'specialized agencies' set up by governments under the aegis of the United Nations to work on a world-wide basis in the cause of one of President Roosevelt's four freedoms—freedom from want. And freedom from want embraces more than food; it includes clothing and shelter. So the Organization also deals with resources which are not directly consumable as food, such as wood and fibres. Furthermore forestry is essentially complementary to farming. In fact from the date of its inauguration in 1945 F.A.O. has devoted a substantial part of its energy and resources to forestry; and this not only in forestry's productive role, but also for the protection and help it can afford to human activity generally, protection from erosion by wind and water, protection from floods, provision of shelter, and help in restoring, maintaining, or building up fertility.

The Headquarters of F.A.O. is now in Rome, having moved there from Washington in 1951. It is housed in two fine modern buildings, one a redundant government office, the other specially built to provide appropriate conference rooms and other office accommodation. Both were made available by the generosity of the Italian Government. The Organization consists essentially of a Director-General appointed by member governments for a term of years, a Deputy Director-General with administrative and information services, and five technical divisions each headed by a Director. These divisions are Agriculture, Economics, Nutrition, Forestry, and Fisheries. The Economics Division is in a sense a part of the agricultural set-up as it deals almost entirely with economics and statistics related to farming and trade in agricultural products. One could say, in fact, that F.A.O.'s activities were divided into four Fs—Farming, Food, Fisheries, Forestry.

Before describing the forestry work of F.A.O. in particular, it may be well to consider briefly what brought the Organization into being, its purpose, and its motive force. The really significant event that led to the creation of F.A.O. was the summoning of a conference by President Roosevelt in 1943 at Hot Springs, Virginia, on 'Food and Agriculture'. But the seeds had been sown much earlier in the 1930's when world-wide agricultural depression had led the League of Nations at Geneva to consider the relationship of nutrition and farming, and begin to seek after joint action between nations to improve both. Not only in this sphere had there been international co-operation. As early as 1905 the International Institute of Agriculture was founded in Rome. Earlier still in 1885 there was held in Namur the Congress of European Forest Experimental Stations

PLATE I (*opposite*). The Headquarters building of the Food and Agricultural Organization of the United Nations (F.A.O.) in Rome (*F.A.O. photograph*).

and Research Organizations, from which developed in due course the International Union of Forest Research Organizations; in the 1930's there was set up the 'Centre International de Silviculture' and the 'Comite International du Bois'. Thus tentative and unco-ordinated efforts towards discussion and action between countries in the field of forestry and agriculture had in fact been going on for many years, and it only required the impetus of a second world war and the vision of a Roosevelt to crystallize them into one organization.

The purpose of the Organization can be set out no better than was done by Mr. Lester Pearson, Chairman of the first F.A.O. Conference, when he said of the Organization: 'It is something new in international history. There have been functional international agencies with more circumscribed objectives and tasks, but F.A.O. is the first which sets out with so bold an aim as that of helping nations to achieve freedom from want. Never before have the nations got together for such a purpose.'

The motive force must be the drive and enthusiasm of the member countries themselves—there are now 72—exerted by the delegates they send to the meetings of F.A.O. But the member countries individually, or meeting together, can and should be stimulated and guided by the Director-General and his staff. The governing body of the Organization is the Conference held every two years, consisting of delegates from all member countries. More detailed supervision is exercised through the Council of 24 member countries, which meets about every six months, as well as by the Co-ordinating Committee and the Committee on Financial Control.

It is the duty of the Director-General to give an account of his stewardship and to put before the Council and Conference his proposals for future policy and action. Grumbles are sometimes heard in this country, as well as elsewhere, that the F.A.O. Secretariat take too much upon themselves and attempt to decide policy and programmes. This same feeling probably shows itself in connexion with other similar United Nations bodies. If there is any truth in this, member countries have only themselves to blame if they do not devote enough time and thought to considering F.A.O. matters and ensuring that there is a high standard and continuity in their representation at meetings.

The work of the Organization is broadly of two kinds. First, there is the intelligence service—the collection and dissemination of statistics and information to help and guide member governments and F.A.O.'s own staff. Secondly, there are programmes of activities carried out by F.A.O. itself in conjunction with and at the request of governments. These activities are again of two kinds. There is the regular programme which is settled and financed directly by member governments meeting at the biennial conference; and there is the 'Expanded Technical Assistance Programme'. E.T.A.P. funds come through the General Assembly of the United Nations and its Technical Assistance Committee, and F.A.O. acts in effect as agent for the United Nations in respect of the type of work that comes naturally within its scope. E.T.A.P. is concerned essentially with helping under-developed countries. Though drawing funds from different sources the two types of activities are closely co-ordinated and both are served by the

same staff at Rome. Similarly technical officers working on E.T.A.P. projects in the field are a valuable source of information for the general intelligence service of the Organization.

It is natural that the Agricultural Division and its sister Economics Division should absorb a major part of F.A.O.'s budget. After allowing for general expenses, the approved percentage allocation of funds between the technical divisions for 1956 demonstrates this clearly. These percentages were as follows. Agriculture 30; Economics 32; Nutrition 10; Fisheries 14; Forestry 14; Total 100.

None-the-less the forestry work of the Organization is world wide, varied and substantial: the 14 per cent. of the funds allocated to forestry represents a little more than half a million dollars (£175,000) and in addition the Forestry Division administers over a million dollars of E.T.A.P.'s funds (£350,000).

Anyone who is cynical about the practical value of international bodies like F.A.O. and sees in them no more than a home for visionaries and theorists may take a more realistic view on closer acquaintance with details of their work. Two items picked at random from the programme of the Agricultural Division illustrate clearly how essential international co-operation is. Foot and mouth disease and locusts are neither of them respecters of national boundaries and in the control of these two ruinous pests countries are increasingly using the services of F.A.O. to organize joint action.

But it is our purpose here to look more particularly at the forestry work of the Organization. As the servant of member countries it is the duty of the Organization to keep itself in close touch with the needs and wishes of governments all over the world. The Forestry Division has arranged to do this rather differently from other Divisions and has set up a number of regional Commissions. There is the oldest, the European Forestry Commission, based on Rome; the Near East Forestry Commission on Cairo; the Latin American Forestry Commission on Rio de Janeiro; the Asia-Pacific Forestry Commission on Bangkok. Because of its special problems there is also a Sub-Commission for the Mediterranean area ('Silva Mediterranea') made up of some member countries of both the European and Near East Commissions. There is no Commission for North America as yet and the U.S.A. and Canada usually send representatives to the European Commission meetings and others. Nor is there a Commission for Africa south of the Sahara. Otherwise the world is covered in this way. Commissions meet about once in two years and they function in two ways. They keep the Director aware of the views of different countries on forestry problems and the way in which they feel F.A.O. can help; this advice the Director takes into account in framing his part of F.A.O.'s programme. The meetings of the Commissions are also occasions for discussion and exchange of information on matters of regional interest during which resolutions may be passed which can be brought to the attention of governments and F.A.O. These Commissions are not in fact executive bodies but are advisory—advisory to F.A.O. and member governments.

As the E.F.C. is the oldest it may be well first to consider some of the matters this Commission has dealt with. Early in its career it formulated principles of forest policy based on recommendations of the Third World Forestry Congress.

It was no mean achievement to get agreement among some 17 countries, many with long-established services and traditions, on the basic principles governing their forestry practices. These principles of forest policy were accepted by the 1951 F.A.O. Conference and now have a world-wide importance and application, particularly for the many countries where the impulse to practice forestry is only just stirring. Early on too the need was felt for information on the whole question of timber resources and demand for forest products. In the absence of such information collected together, analysed, and published in an understandable form it is difficult for individual countries to judge whether their own particular forestry plans based mainly on national considerations make sense when viewed against the wider background of world or regional supply and demand. To meet this need there was undertaken an investigation into the resources of Europe in timber, a critical examination of the ways in which wood is used and the quantities of forest products absorbed, and a forecast of future developments. F.A.O. did not work alone in this matter. Another United Nations body, the Economic Commission for Europe, is concerned amongst other things with timber and forest products and has set up a Timber Committee. The spheres of interest of this Timber Committee and the European Forestry Commission can be broadly distinguished by saying that the Commission is concerned primarily with growing, the Timber Committee with use of timber and timber products. But it is clearly impossible to draw a hard line between the interests of the two bodies and in order to avoid overlapping and unnecessary duplication of work it has been arranged that the Timber Committee should be served by a secretariat provided largely by F.A.O. The Deputy Director of the Forestry Division of F.A.O. is also Director of the E.C.E./F.A.O. Timber Division and the joint secretariat is based on Geneva which is the headquarters of E.C.E. This is a good example of sensible and effective co-operation between two international bodies, and the fruits of their co-operation were first seen by the publication of *The Study on European Timber Trends and Prospects*. It is not possible here to discuss this study in any detail. The whole problem is a most complex one made difficult by the different standards of statistics which can be obtained from the many countries involved; and looking to the future inevitably involves opinion and not fact. Very briefly, the study sees no reason to forecast a falling off in demand, though there will be a change in the form in which timber is used. On the contrary the need for products of the forest will steadily increase. Even if more of the huge Russian production finds its way into the rest of Europe, the forests of this region will be hard put to it to meet rising needs. There is therefore full justification for individual countries to plan for improving output from existing forests and increasing the area under timber crops—for what the study describes as a 'dynamic forest policy' for Europe. The study was discussed at a joint session of the European Forestry Commission and the Timber Committee of E.C.E. in Rome in 1953 and on the recommendation of the European Forestry Commission the study was accepted by the F.A.O. Conference later the same year. This is not to say that it passed without criticism. It received serious criticism in particular for its forecasts from the Timber Trade of the United Kingdom and also from some

Scandinavian countries. None-the-less few would deny that the study was an ambitious undertaking, skilfully carried out and presented with imagination and foresight. Already in the months that have elapsed since it was written the trends that were forecast appear to be taking place and, although it is too soon wholly to judge, the faith of the authors in their work is being shown to be justified. The study, reviewed periodically as it will be, is an important contribution to knowledge of the world's most versatile raw material.

The publication of this study has inevitably called forth demands for similar work to be undertaken in other regions, and indeed the 1955 Conference approved in principle that a more limited study should be made for the Far East. The difficulties in this region will be far greater than for Europe because of the inadequacy or almost total absence of statistics in some countries. This difficulty is recognized but F.A.O. believes that a beginning should be made in the collection of data, for this in itself will stimulate countries to improve their own knowledge of their forests.

A rather similar project of the Forestry Division has been the compilation of a World Forest Inventory. The first was done in 1948; the second in 1953 was an appreciably better assessment; and the third, planned for 1958, will be yet more accurate as more and more countries carry out or revise their own inventories. Again in very broad terms the conclusion to be drawn from the 1953 World Inventory is that the usable growth from coniferous forests at present exploited just about balances demand, while growth in broadleaved forests greatly exceeds demand. Future world requirements which are expanding, particularly for pulp, can be met partly by exploiting untapped coniferous forests and partly by devising means of using excess growth of broadleaved species. We need not therefore fear a timber famine; if shortages occur it will be for economic reasons rather than lack of wood.

On a more strictly practical plane the E.F.C. has fostered and continues to encourage the study and exchange of information on a number of matters. Torrent and avalanche damage is serious in many parts of Europe, particularly in the south and centre, and a working party to deal with this has been functioning for a number of years. This is not just a forestry problem but one involving agriculturalists and engineers. Exchange of experience and the latest technique is found of considerable value to countries like Switzerland and Italy. Another problem facing every European country is the restoration and improvement of existing woodland and the establishment of forest on bare land—the implementation, in fact, of part of the dynamic forest policy advocated in the Timber Trends Study. Here again a Working Party on Afforestation and Reforestation has been at work and a study tour in the south of France took place in 1956 to examine and discuss the extensive work being done by the French forest service and private forest owners. From the point of view of the U.K. perhaps the most useful work being done is on Forestry Techniques and Training of Forest Workers. A committee on this subject was originally set up by the E.F.C. but this was expanded in 1954 into a joint working party of F.A.O. and E.C.E.—another example of the close tie between the two bodies. This working party is concerned on the one hand

with finding the best methods of carrying out forestry operations, particularly in logging, and testing tools and machines which help in these operations; and on the other hand with devising means of teaching workers how best to put proved methods into general practice. The whole objective is increased efficiency resulting in better pay and conditions for workers, cheapening of forest products, and greater prosperity for the whole forestry industry. This work is in effect what we in this country know as 'work study', an activity widely practised in industry, but to which little attention has as yet been paid in forestry here. This joint working party carries out its numerous investigations through the medium of small working groups or individuals who are experts in any particular subject. These groups are serviced by the Secretariat but can do much by correspondence. They are therefore a quick and relatively cheap method of getting results. Similarly the E.F.C. works mainly through sub-committees and working parties, the large parent body meeting only occasionally to oversee and guide its offspring. This is a good and economical way in which otherwise cumbersome organizations can function successfully.

The other Forestry Commissions are younger but they are working in much the same way as the E.F.C. Mention of some of their activities will give an idea of the field they cover.

Watershed management is a subject being given particular attention by the Asia-Pacific Forestry Commission; fire control by the Latin American Forestry Commission. Grading and standardization of timber and its products is a thorny problem even in the older forestry countries and both regions are rightly concerned with this matter. In all regions too the development of research institutes and co-ordination of research work is being given a high priority. The Near East Forestry Commission is the most recently formed and held its first meeting in 1955. It is concentrating first on such fundamental matters as national forest policies, grazing management—a basic problem in this region—and proper forest management and conservation which can usually only be effective where grazing can be controlled. Publicity for forestry is another subject continually before the Commissions and is of special importance in many under-developed countries where even the most elementary knowledge of forestry or understanding of its role is entirely or almost wholly lacking amongst people and government alike.

There are, too, subjects which are world wide rather than regional and F.A.O. deals with these through special Commissions. There is the Poplar Commission, for instance, which has been working for some years gathering and spreading information about this tree. Poplar can take an increasingly important place in many countries if the right species and varieties are chosen, and the correct techniques used to grow and use the timber. Eucalyptus is another tree of increasing world-wide importance which fully justifies the attention given to it; likewise chestnut and teak.

About every five years there is held a World Forestry Congress. These meetings began before F.A.O. was created, the first being held in Rome in 1926. Since the 1949 Congress in Finland F.A.O. has taken a prominent part in organizing the meetings in conjunction with the host country and finds the discussions and

resolutions passed a most useful and in fact essential guide in framing its future plans and policy.

In the use of timber there has been no more startling expansion than in the pulp market. There is a clear relationship between the use of paper and the rising education and living standards of the growing world population. Much attention is being paid to likely demand, and importing countries must consider whether their own unused timber resources could be developed and whether their exploitable supplies justify establishing a pulping industry of their own. This is just the sort of problem in which F:A.O. can be of the greatest help with their world-wide coverage and the experts they can call on. South America is a region where living standards can be greatly improved and where pulp is imported in quantity in spite of vast untapped forest resources. So a conference on the whole subject was held in Buenos Aires in 1954 following a study made by F.A.O.[1] This kind of investigation is an essential background for any policy decision by individual countries on long-term developments. The United States Forest Service has lately completed a 'Timber Resources Review' for their country. It is a massive and impressive document which clearly forecasts that with all its huge resources the U.S.A. will be hard put to it to meet the requirements of wood, particularly for pulp, that are expected by the end of the century. The United States can make a study for its own vast territory; no one but F.A.O. is equipped to make even a guess at the timber situation in most other regions of the world.

In the matter of publications F.A.O. issue a considerable quantity every year. Some are regular, like the quarterly review of forestry and forest products *Unasylva*, which includes helpful 'equipment news' bringing together notes on machinery useful in forestry from all over the world. There are various statistical bulletins. Other publications include studies of particular subjects as these are investigated. For the classification of forest literature F.A.O. has recommended the world-wide use of the Oxford System of Decimal Classification. The Organization is working towards the compilation of a multilingual forest terminology largely through the agency of the Commonwealth Forestry Bureau at Oxford. In the two latter projects F.A.O. works closely with I.U.F.R.O.—International Union of Forest Research Organizations—as indeed it does in all matters concerning forest research.

Work carried out under the 'Expanded Technical Assistance Programme' of the United Nations represents the 'action arm' of F.A.O., supplementing and closely integrated with the Regular Programme. It consists essentially of *ad hoc* projects undertaken at the request of individual governments with help both financial and other provided by the country concerned. A few examples of current projects will indicate the wide range being covered. Assistance in formulating forest policy and establishing a forest administration is being given to Brazil and Iran; an expert is in Yugoslavia to help the country work out a programme of soil conservation, watershed management, and torrent control; Burma is getting help and advice in setting up a Research Institute and a Forest Products Research Laboratory; Turkey needs a large afforestation and reforestation programme and

[1] *World Pulp and Paper Resources and Prospects.*

is being given advice on the right silvicultural methods to adopt and help in preparing working plans. In all so far there have been 100 missions in 40 countries since E.T.A.P. began in 1950. The work of the Forestry Division is to consider and discuss requests for help from individual countries, choose and recruit a suitable expert or experts for each mission, and thoroughly brief the expert. Finally the form of the report has to be settled and sent to the country concerned and any necessary follow up work undertaken. The essential point about E.T.A.P. is that the missions are not intended to be in any way permanent, but are designed simply to 'prime the pump'. An important part of the programme is the provision of scholarships so that a country's own staff can be trained to carry on the work that the mission begins.

It has been possible here to mention but a few of the activities of F.A.O. in the field of forestry. This field is a very wide one—inevitably so because forests, associated grazing lands, and wastes account for some two-thirds of the world's land surface. A great part of this area is producing nothing or far below capacity. It is one of the great tasks facing forestry to help to make these areas of greater use to man. As Lord Samuel once said 'The desert is not an unfertile region. It is only asleep.' Perhaps it is as well that there is so much land producing far below capacity, because somehow the needs of the world population increasing at the net rate of over 100,000 a day must be met. So far as wood is concerned the 'developed' countries can improve their output. But this is not enough. The 'under-developed' countries are the reservoir for future prosperity. The knowledge and experience of how to release their latent wealth is often not there but rests in the 'developed' lands. F.A.O. is a bridge between the two.

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THE INFLUENCE OF HIGH PRUNING ON THE GROWTH OF DOUGLAS FIR

By R. LEHTPERE

SUMMARY

In a heavily thinned 11-year-old Douglas fir (*Pseudotsuga taxifolia* Brit.) plantation of Qu. Cl. I at Dartington in South Devon, selected trees were pruned to half height and the average length of the live crown was reduced by 32 per cent. (1) At the end of the first growing season after pruning a significant reduction of the girth increment at breast height in all girth classes was determined. (2) In the second growing season this reduction was only in the lower girth classes. (3) In the third growing season the growth of the pruned trees at breast height was a little, but not significantly, better than that of the control trees. (4) There was no significant reduction in the girth increment at 15 feet, i.e. above the removed branches, nor was the height growth affected by pruning. (5) It appears that the suppressed part of the live crown does not contribute to timber production. (6) The scars of removed branches heal sooner on the faster-growing trees.

WHEN selected trees in a Douglas fir plantation, 11 years old, were being pruned to half height, the average length of the live crown was reduced by 32 per cent.; this provided an opportunity for testing the influence of high pruning on the growth of the trees. An experiment was arranged by which the growth of pruned trees could be compared with that of similar trees which were left unpruned. The comparison appears to show (1) that pruning had no effect on the height growth of the trees, (2) that it caused a significant but temporary retardation in the diameter growth at breast height, (3) that the diameter growth at 15 feet from the ground, i.e. just below the remaining unpruned branches, was unaffected.

DESCRIPTION OF THE PRUNED PLANTATION

The experiment was established in March 1953 in North Wood at Dartington in South Devon. In this wood the soil-forming rock is the middle Devonian shale, which has developed into a brown soil—a deep porous loam. The soil reaction is moderately acid. The previous crop was an open hardwood plantation, mostly oak with ground vegetation of bramble and bracken.

The plantation was made in 1942 at 6 feet × 6 feet with Douglas fir and Sitka spruce in alternate rows and with a few redwoods in the Sitka rows. The Douglas fir had a good start and suppressed many of the Sitka spruce which now provides only 10 per cent. of the trees in the canopy. The plantation was brashed up to 7 feet in 1950 and a heavy first thinning was done in 1950–1 at the age of 9 years. For figures about the sample plot see Table I. Taking the Forestry Commission Revised Yield Table for Douglas fir (1) as the standard, the plantation belongs to 1st qu. cl. and has about the same M.A.I. The C.A.I. is lower but it is not entirely comparable because we have calculated the C.A.I. for a five-year period instead of the three-year period used in the Forestry Commission Yield Table.

We have had considerable experience with Douglas fir in this locality. A 53-year Douglas fir stand, close to the young plantation, has 96 trees per acre, standing volume 6,300 h.ft. o.b., mean b.h.q.g. 13·4 inches. It is growing at an average rate of 8·6 rings per inch at breast height. In spite of light thinning in youth, the falling off of dead branches was delayed and certainly the timber quality would have been much higher if the trees had been pruned while they were young.

TABLE I. *North Wood, Compt. IV. Douglas fir at age 14 years in November 1955. Figures per acre.*

Species	*Top height (ft.)*	*No. of trees*	*B.H.Q.G. (in.)*	*Basal area (b.sq.ft.)*	*Volume (h.ft. o.b.)*	*C.A.I. (h.ft. o.b.)*	*M.A.I. (h.ft. o.b.)*
Douglas fir .	40·0	461	4·6	68·1	1,235	180	107
Sitka spruce .	..	267	2·8	14·6	146	22	11
Redwood . .	..	21	6·7	6·4	126	21	9
Total . . .		749		89·1	1,507	223	127

Meteorological data. According to the Dartington meteorological station, which is about 1 mile from the plantation, the total rainfall from the establishment of the plantation (1942) to the beginning of the experiment (1953) has been 505·22 inches or 45·92 inches per annum. The average rainfall for the growing season (from April to October) was 16·91 inches. During the experiment the meteorological data was as follows:

Year	*Total rainfall in year (in.)*	*Rainfall in growing season (in.)*	*Mean temperature*	
			in year	*in growing season*
1953 . . .	31·54	17·18	50·2	53·6
1954 . . .	49·87	17·00	49·5	52·1
1955 . . .	44·45	14·01	49·6	53·3
Average . .	41·95	16·06	49·7	53·0

Diseases. During the experimental period the trees retained about 3 years' needles despite slight attacks of aphis (*Adelges cooleyi*) and leaf-cast (*Phaeocryptopus gäumannii*).

EXPERIMENTAL PROCEDURE

In the young plantation 200 Douglas fir per acre—trees that might be suitable for the final crop—were marked for pruning in 1952–3. From these trees 50 pairs were taken for experiment from all diameter classes and were divided into two groups at random. One group, 50 trees, was left for control and the other group was pruned up to 16 feet, i.e. about half the tree length. On the average, green branches were removed from a length of 8·5 to 16 feet above the ground, so the

crown length was reduced by 32 per cent. On most of the trees three lower whorls were removed and on the average five whorls left. The following measurements were taken:

(*a*) The heights of all the experimental trees were measured with a Haga altimeter in March 1953 and in November 1955.

(*b*) Rings were painted on the trees at breast height and at 15 feet, and girth at both heights was measured each year. A flexible steel tape was used and girths were measured to the nearest millimetre.

The following particulars were recorded of the living branches immediately after their removal in the pruning:

(*a*) Total weight of branches of each whorl.

(*b*) Average length of branches of each whorl.

(*c*) The 'apical growth' in the year 1952, i.e. the annual growth of the leading shoot of the branch. (The recorded figure was the average apical growth of the five branches in each whorl which had the biggest apical growth in 1952.)

PRUNING EFFECT ON GIRTH GROWTH

The average results of girth measurements at breast height and at 15 feet are given in Table II. In 1953, at the end of the first growing season after pruning,[1] the average girth increment reduction of pruned trees at breast height is 0·36 inches. As will be seen later from the graph, the reduction of girth increment is significant in all girth classes.

In 1954, at the end of the second growing season, the average girth increment of the pruned trees is smaller than that of the control trees by 0·13 inches. In the smaller trees, i.e. those with the smaller girth, the reduction in growth is significant, but in the larger trees it is not.

In the third growing season, 1955, the average increment of the pruned trees was slightly bigger than that of the unpruned trees, but the differences are not significant in any of the diameter classes.

TABLE II. *Girth measurements at breast height and at 15 feet from 1953 to 1955*

No. of trees	*Mean girth at breast height March 1953 (in.)*	*Girth increment at breast height*			*Mean girth at 15 ft. March 1953 (in.)*	*Girth increment at 15 ft.*		
		1953 (in.)	*1954 (in.)*	*1955 (in.)*		*1953 (in.)*	*1954 (in.)*	*1955 (in.)*
Pruned trees 50 .	17·25	1·35	1·20	0·96	11·71	2·20	1·50	1·14
Control trees 50 .	17·25	1·71	1·33	0·90	11·37	2·27	1·57	1·14
Difference . .	0	−0·36	−0·13	+0·06	0·34	−0·07	−0·07	0

[1] Actually the girth growth of 1953 was measured in March 1954, growth of 1954 in March 1955, and growth of 1955 in November 1955.

Differences of girth increment in the pruned and control trees at 15 feet, contrary to the breast height differences, are very small in all three growing seasons. The differences are not significant in any of the girth classes, and as far as can be seen in this experiment the girth growth at 15 feet, i.e. above the removed branches, has not been affected by pruning.

STATISTICAL ANALYSES

According to Schumacher and Chapman (2) the trees included in this experiment are 'purposive selected' and the statistical analyses of the measurements are limited. But the statistical calculations can still be made on the regression lines and on the significance of regression coefficients, and the distance between the regression lines can be analysed.

Regressions were calculated as follows:

(*a*) Girth increment at breast height on breast height girth.
(*b*) Girth increment at 15 feet on breast height girth.

The regressions were calculated for pruned and control trees for each of three growing seasons. Two sets of calculations were made; in the first set the independent variable was the original breast height girth or girth in March 1953, and in the second set the independent variable was the breast height girth at the end of the 1953, 1954, and 1955 growing seasons. The regression lines of both sets of calculations are analogous, but the regression coefficients in the second set of regression lines, shown in Figs. 1 to 3, are considerably more significant. In order to compare on the graphs the girth increments of trees with equal breast height girth at the beginning of the experiment, the difference in girth increments of pruned and control trees must be taken into account.

The continuous line *P* in Fig. 1 refers to the growth of the pruned trees in the first year; it shows the relationship of the girth increment at breast height to the girth at breast height at the end of the year. Similarly, the line *C* shows this relationship in the control trees in this year. The lines *P* and *C* in Figs. 2 and 3 show the same relationships in the second and third year. The lines P_1 in Figs. 1, 2, and 3, show the relationship of girth increments at 15 feet to the girth at breast height in the pruned trees, and lines C_1 the same relationship in the control trees.

It is clear from these graphs that in the first year there is a marked difference between the breast height increments of the pruned and the control trees. There is also a considerable difference in the smaller trees in the second year. A test must now be applied to see whether these differences between the regression lines are significant. So the variances of the girth increments were calculated by the following formula from Schumacher and Chapman,[1] $V_{(y)} = V_{(a)} + (x - \text{-})^2 [V_{(b)}]$, which was worked out for six values of breast height girths for each regression line. The significance of the differences between the regression lines is shown on the graphs in the following way. The dotted line *p* on Fig. 1 is drawn at the distance of one standard error from the regression line *P*, and the dotted line *c* is drawn at one standard error from the regression line *C*. Where the two dotted lines coincide, as at the point *K* in Fig. 2, the difference between the lines *P* and *C* is two standard errors. On the graphs the dotted lines are drawn in places where the difference between regression lines is more than two standard errors; so in these places the differences are significant at a 5 per cent. probability level, or better.

Statistical consideration of regression coefficients. The regression coefficients of all 12

[1] Formula given by Schumacher and Chapman (1942): y = girth increment; x = girth at breast height; a = regression constant; b = regression coefficient; $V_{(y)}$, $V_{(a)}$, $V_{(b)}$, = variance of y, a, and b respectively.

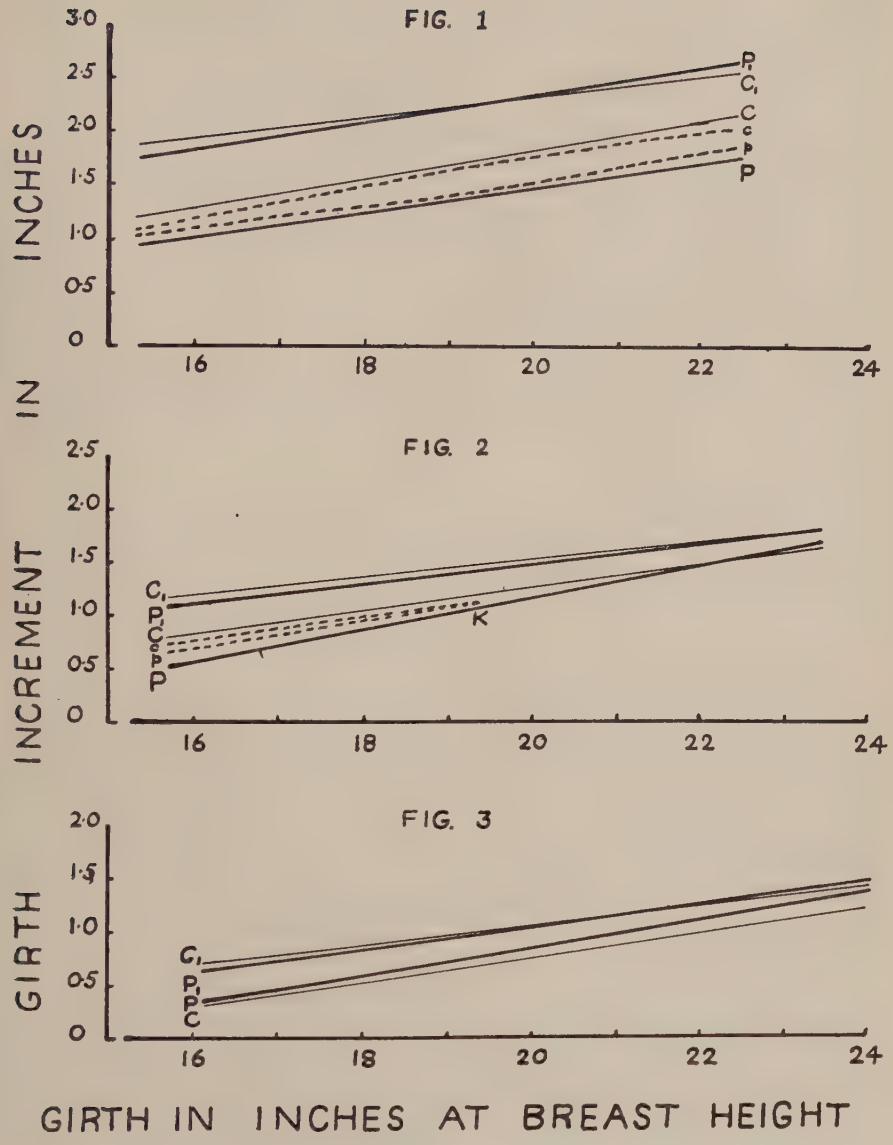

Fig. 1. Girth increment at breast height and at 15 feet in 1953 on breast height girth at end of 1953.

Fig. 2. Girth increment at breast height and at 15 feet in 1954 on breast height girth at end of 1954.

Fig. 3. Girth increment at breast height and at 15 feet in 1955 on breast height girth at end of 1955.

For explanation of lettering, see text on page opposite.

regressions are very significant. This means that with increase of girth at breast height there are corresponding significant average increases in girth increments at breast height as well as at 15 feet.

If we compare regression coefficients of lines P, P_1, C, and C_1 of the same year, then in general their differences are small and do not differ significantly. So there is no evidence that the increase of girth increments proceed at different rates, except in 1954 when the difference of regression coefficients of P and C_1 lines is at the 1 per cent. probability level.

Statistical consideration of distance between the regression lines. The results of statistical analyses of distance between the regression lines, i.e. the differences of girth increments, of pruned and unpruned trees at breast height as well as at 15 feet, has been given above in the section on pruning effect on girth growth and is shown in Figs. 1 to 3. Since, in 1954, the difference in regression coefficients of P and C regression lines is at 7 per cent. probability level, which is not significant, the trees of lower girth classes were analysed separately from those of higher girth classes by the t test. In this case the girth increments of the 25 smaller pruned trees were compared with corresponding control trees. It was found that at breast height these pruned trees had significantly smaller girth increments than the control trees.

THE HEIGHT GROWTH

The mean height of pruned and unpruned trees in 1953 was 31·5 feet. In 3 years the pruned trees have grown on average 9·3 feet and unpruned trees 9·2 feet. The difference in height growth is very small and within the error of measurement.

DESCRIPTION OF REMOVED PART OF CROWN

Weight of removed branches in each whorl. All the trees had been brashed to 7 feet 2 years before the experiment was started. Pruning of live branches from 8·5 feet to 16 feet removed three whorls of branches on most of the trees. Fig. 4 shows the relationship between the weight of the branches in each whorl which were removed and the breast height girth of the trees. The average weights of live branches of the bottom, middle, and top whorls have been plotted respectively against the original breast height girths, and points have been smoothed linearly. The line (*d*) on the graph represents the average weights of the branches removed in the bottom whorl, (*c*) of the middle whorl, (*b*) the top whorl, and (*a*) represents the sum of all the branches. It will be seen from the graphs that on the average the weights of the whorls of branches increase from below upwards. Also, this increase is more marked in the larger trees than in the smaller trees. Out of 46 trees, however, from which the measurements were taken, the branches in the top whorls of 7 trees had a lower weight than that of the middle ones. The lowest remaining branches could not, of course, be weighed, but on most trees they appeared to be lighter than the removed branches in the top whorls.

Length of branches and their 1952 apical growth. The average lengths of the removed branches in each whorl and their average 1952 apical growth (taken from the five longest apical growths in the whorl) are shown in Table III. The average lengths vary remarkably little:

(*a*) On the average the branches of the bottom whorls are 0·4 feet shorter than those of the top whorls.

(*b*) The branches of the top whorls of the smaller trees are 0·5 feet shorter than those of the bigger trees.

(*c*) The length of the branches of the bottom whorls of the smaller trees is 0·2 feet shorter than that of the bigger trees.

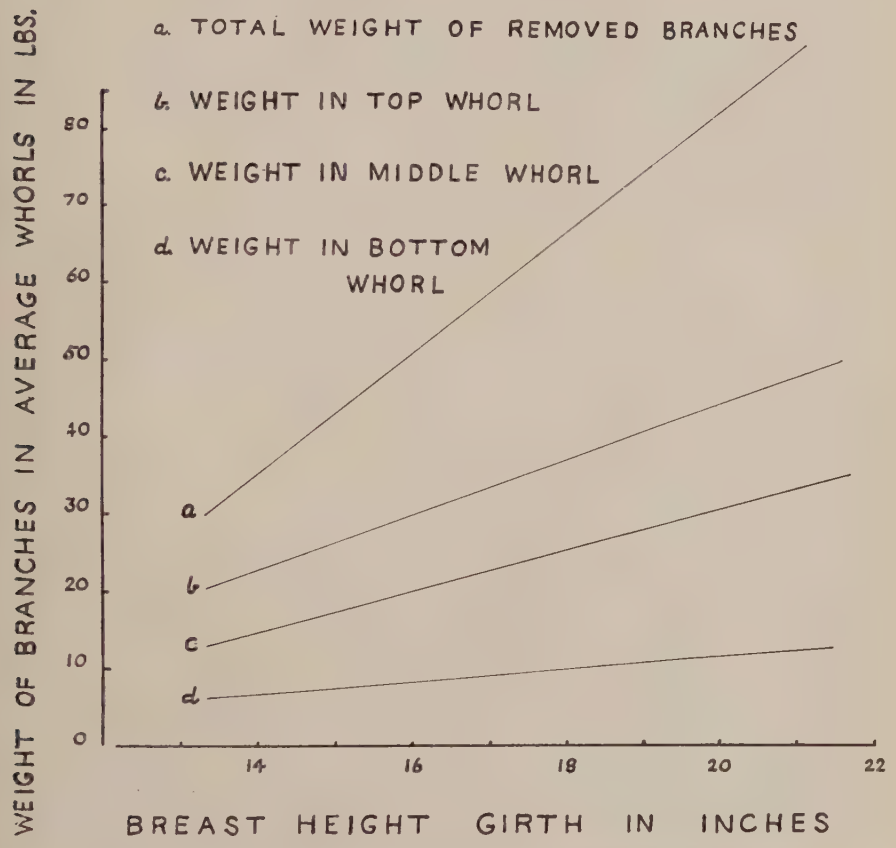

Fig. 4. Weight of branches in an average whorl against breast height girth.

Similarly, in the case of weight, it is likely that unremoved lowest branches were also shorter than those of removed top whorls.

In 1952 the average of the main current year's shoots of the branches in the top whorls was 10·0 inches and these shoots had well-developed end buds; in the bottom whorls it was 3·9 inches and the terminal buds were considerably smaller. The branches of the top and middle whorls of the smaller trees had about 1 inch shorter annual shoots than those of the bigger trees, but in the bottom whorls this trend was not pronounced.

THE INFLUENCE OF EACH WHORL OF BRANCHES ON TIMBER PRODUCTION

We have seen above that the reduction of ring width caused by pruning was significant at breast height but not at 15 feet. We will now consider the relation-

ship of the girth increment at 15 feet to that at breast height. This is expressed by the fraction $\Delta G_{15}/\Delta G_{B.H.}$, where ΔG_{15} is the annual increment in girth at 15 feet and $\Delta G_{B.H.}$ is the corresponding girth increment at breast height. The mean values of this fraction are shown in Table IV. In 1953 when the girth increment reduction at breast height of pruned trees was biggest, the difference in the relationship between pruned and control trees was +0·37, but in 1955, when the pruned trees had grown a little better at breast height, this difference is −0·06. So the relationship $\Delta G_{15}/\Delta G_{B.H.}$ changes according to the pruning effect and it can be used for the estimation of the usefulness of the branches in a whorl on the tree diameter growth in the following way.

TABLE III. *Figures for removed part of crown. Average per tree.*

	Weight of removed whorls (*lb.*)	*Length of removed branches* (*ft.*)	*1952 apical growth of removed branches* (*in.*)
Top whorl	33·8	7·1	10·0
Middle whorl . . .	23·6	6·9	6·3
Bottom whorl . . .	8·6	6·7	3·9
Total per tree . .	66·0		
Average		6·9	6·7

In 1953 $\Delta G_{15}/\Delta G_{B.H.}$ averaged 1·72 for the pruned trees and 1·35 for the control trees; so pruning had a significant influence on the relationship. 20 pruned trees in which $\Delta G_{15}/\Delta G_{B.H.}$ was 1·60 (1·60 equals 1·35 plus one standard deviation) or higher, were picked out and their average breast height girth was found to be 18·0 inches. Seven pruned trees, in which $\Delta G_{15}/\Delta G_{B.H.}$ was 1·35 or less, were also picked out, and their average breast height girth was 17·6 inches (see Table V). It appears that, in comparison with the first group, the second group was little affected by pruning. The average apical growth of the branches in the removed top whorls for the first group was 11·6 inches in 1952 and for the second group it was 8·1 inches. These means—11·6 and 8·1—were analysed by the *t* test and were found to be significantly different at 1 per cent. probability level. So it appears that, in this plantation, at the time of this pruning, the whorls in which the branches increased in length on an average by about 8 inches in 1952 had little influence on timber production, but whorls with width increment of about 12 inches added to the growth of the main stem.

TABLE IV. *Girth increment at 15 feet divided by girth increment at breast height.* $\Delta G_{15}/\Delta G_{B.H.}$

	1953	*1954*	*1955*
Pruned trees . . .	1·72	1·40	1·30
Control trees . . .	1·35	1·21	1·36
Difference . . .	0·37	0·19	−0·06

TABLE V. *Girth increment at 15 feet divided by girth increment at breast height in two groups.*

	No. of trees	*Mean girth (in.)*	*Average* $\Delta G_{15}/\Delta G_{B.H.}$		*1952 average apical growth of removed branches (in.)*
			1953	*1955*	
$\Delta G_{15}/\Delta G_{B.H.}$ over 1·60 . .	20	18·0	2·05	1·35	11·6
$\Delta G_{15}/\Delta G_{B.H.}$ under 1·35 .	7	17·6	1·25	1·05	8·1
Difference			0·80	0·30	3·5

GIRTH GROWTH AND SUPPRESSION OF CROWN

In November 1955, at the end of the experiment, the extent to which the branches of control trees had died was examined. It was found that on 17 trees the branches were dead to 15 feet, 33 trees had one suppressed, but still living, whorl of branches, and on 7 trees two whorls of branches below 15 feet were still alive.

Fig. 5 shows how the girth growth of pruned and unpruned trees has equalized during the 3-year period. In the graph the mean girth increments are plotted against the years. It can be seen that the annual girth increment of the control, as well as that of the pruned trees, has fallen, but that the fall off of breast height girth increment of the unpruned trees was greater. The decrease in the girth increment at 15 feet was greater than that at breast height, which might be due to the distance between these points becoming smaller in relation to the height of the trees.

In 1955 the girth increment of the pruned trees was no less than, in fact it was slightly larger than, that of the control trees. These observations suggest that suppressed branches of the control trees did not contribute to the growth of the main stems. It is even possible that their removal before they are dead may have a favourable influence on timber production.

WHICH PART OF THE CROWN CONTRIBUTES TO TIMBER PRODUCTION?

One of the aims of pruning studies is to determine how much of the crown contributes to timber production. According to Stein (3) one-third of the length of the live crown of Douglas fir can be removed without causing an important reduction in height and diameter growth. His experiment was carried out at Cardon in Washington in a 28-year-old stand, of site class IV, which was from moderately to well stocked. Weck (4) in Germany also states that removing one-third of the live crown has no effect on Douglas fir growth providing that a crown ratio of at least 40 per cent. is left. The experiment at Dartington has shown that an average reduction of the live crown by 32 per cent., leaving a crown proportion of 50 per cent., has diminished diameter growth at breast height significantly in the first growing season. This occurred in all girth classes. In the second growing

season only the lower girth classes were affected. These dissimilar results may be due to different experimental conditions. However, the Dartington results agree with Zederhauer (5) who has found that crown reduction of Douglas fir by one-third reduces the growth of pruned trees.

It would be useful if we had some means of distinguishing the branches in a plantation which have ceased, or soon will cease, to contribute to timber production. As branches become suppressed their apical growth decreases and it may be

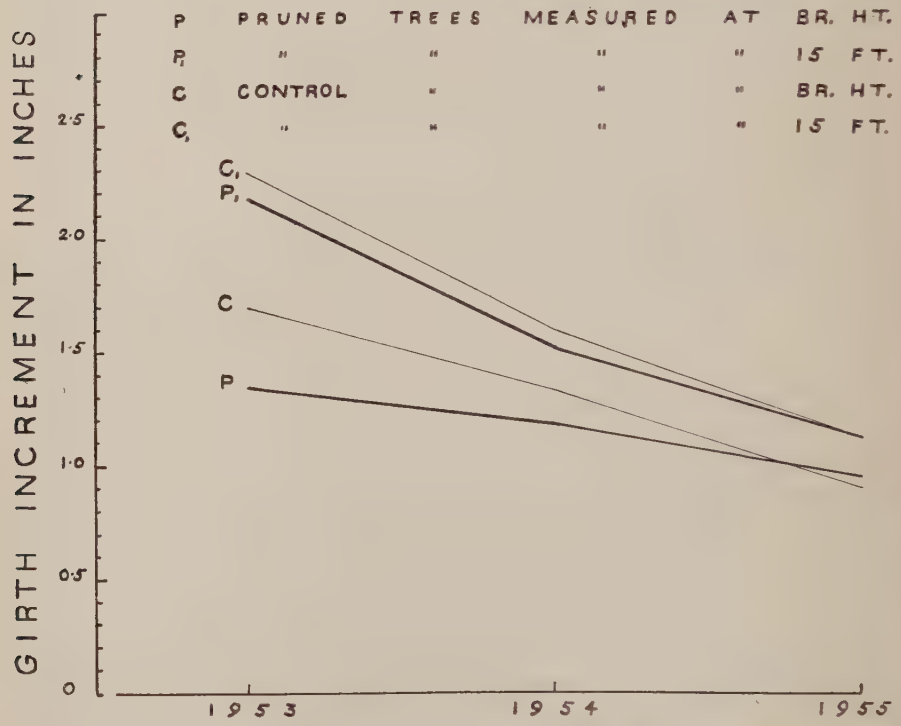

Fig. 5. Girth increment at breast height and at 15 feet from 1953 to 1955.

found that the length of the apical growth provides an indication of their continued usefulness. In the Dartington experiment it appeared that whorls in the lower half of a tree, with branches which had an average apical growth of 8 inches or less, do not contribute to the basal area increment; but this is a fast-growing plantation. In plantations which are growing more slowly a branch with this apical growth might still be helping to feed the tree. So it may be useful to express the apical growth of the branches as a fraction of the apical growth of the main stems of the trees. The average annual height growth of the Dartington trees was about 37 inches, so if the apical growth of the critical branches was 8 inches, the fraction $\frac{\text{apical growth of branch}}{\text{apical growth of main stem}}$ was about 0·22. It would be interesting to know whether, in plantations which were growing less rapidly,

branches ceased to contribute to the basal area increment when their apical growth sunk to less than about one-quarter of that of the main stem.

HEALING OF BRANCH WOUNDS

Observations on the extent to which the wounds left by pruning had healed were made at the end of 1954 and 1955, i.e. after two and three growing seasons respectively. The numbers of healed and unhealed scars were counted and the criterion for healing was that the scars should be entirely overgrown by bark. Twenty trees were examined of which the first group of 10 trees had the largest girth increment in the first 2 years of the experiment and the second group of 10 trees had the smallest increment. Particulars of these trees are given in Table VI. It can be seen from the table that the groups differ little in mean branch length and weight, and in girth the difference is only 1·6 inches. So we can assume that the scars in both groups were about the same size. In the 1954 counts, healing in the first group, with an average rate of growth corresponding to 3·6 rings per inch, was 59 per cent., and in the second group, with the rate of growth 6·5 rings per inch, 28 per cent. In 1955 the figures were 91 per cent. and 61 per cent. respectively. It was observed that often very small branches (under 0·3 inches in diameter) did not make good progress in healing and many of these were still unhealed in 1955. These small branches were often not sawn off smoothly but were torn off by the saw.

TABLE VI. *Healing of branch wounds*

Group	*No. of trees*	*Average girth at B.H. March 1953 (in.)*	*Average girth increment in the years 1953–4–5 at*		*No. of rings per inch: average of B.H. and 15 ft.*	*Average weight of single branch (lb.)*
			B.H. (in.)	*15 ft. (in.)*		
(1)	(2)	(3)	(4)	(5)	(6)	(7)
I .	10	18·3	5·1	5·7	3·6	1·8
II .	10	16·7	2·0	4·0	6·5	1·8

Group	*Average length of branches (ft.)*	*Total no. of scars under observation*	*Healed scars*			
			in 1953 and 1954 growing seasons		*In 1953, 1954, and 1955 growing seasons*	
			Total no.	*% age of col. 9*	*Total no.*	*% age of col. 9*
	(8)	(9)	(10)	(11)	(12)	(13)
I .	7·0	342	202	59	310	91
II .	7·1	285	81	28	175	61

In 1955 fructifications of a fungus were found on some unhealed scars of the pruned trees. A specimen was sent to the Imperial Forestry Institute where Mr.

W. R. Day identified it as *Sterum sanguinolentum*. Mr. Day had previously isolated this fungus from the heart-wood of the main stem of spruce and Japanese larch which had not been pruned, so we cannot be certain that infection in this case was due to live pruning. The experimental trees were pruned in March and those which were not required for the experiment were pruned a month later. Fructifications were found both on the experimental trees and on the remaining trees.

ACKNOWLEDGEMENTS

I would like to express my thanks to the Dartington Hall Trustees for providing the means and the meteorological data for this research, to Mr. W. E. Hiley who encouraged me to do the work, read the paper and gave valuable advice, and to Mr. W. R. Day for his kindness in identifying *Sterum sanguinolentum*.

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NOTE ON THE FIRST BRITISH OCCURRENCE OF *IPS CEMBRAE* HEER (COL. SCOLYTIDAE)

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SUMMARY

During 1955 the larch bark beetle, *Ips cembrae* Heer, was discovered in twenty-nine localities in Moray, Nairn, Banff, and Inverness. These are the first British records for this species. It is assumed that *I. cembrae* entered the country in post-war shipments of German timber and has persisted in small numbers until the damage to woodlands caused by the gale in 1953 provided favourable conditions for its increase. A conspicuous feature of attack is the twig tunnelling of the adult beetles which produces crown pruning. In one locality *I. cembrae* succeeded in breeding in and killing standing European larch of some 45 years of age.

INTRODUCTORY

IN August 1955 the larch bark beetle *Ips cembrae* Heer was found for the first time in Britain in Monaughty Forest, Morayshire. Consequent upon this discovery a survey revealed that this species is fairly widely distributed in the north-east of Scotland, appearing to be centred in Morayshire but also extending into Nairnshire, Banffshire, Inverness-shire, and Ross-shire. Although *I. cembrae* has not hitherto been recorded from Britain, two closely related species *I. typographus* L. and *I. amitinus* Eich. entered the country in large numbers on German spruce and pine timber in the immediate post-war years (5, 7). Neither of these latter species, however, appears to have become established here, although Duffy includes *typographus* in his British key (3).

Much confusion has in the past existed about the distinction of *I. cembrae*, *I. amitinus*, and *I. typographus*. This is partly because of their close morphological similarity, and partly because of some overlap in their ranges of host tree preference. Reliable characteristics for identification are now, however, recognized (see below) and the more recent authorities (9, 10, 11) are agreed that the normal host for *I. cembrae* is *Larix decidua* Mill. The distribution of the beetle closely follows that of the host tree and *I. cembrae* has also, on the continent of Europe, colonised plantations of *L. decidua* outside the normal range of that tree species.

DESCRIPTION AND LIFE CYCLE

The genus *Ips* can be readily identified among the Scolytids (1, 3). In *I. cembrae*, as in other members of the genus, the apices of the elytra are excavated and the sides of this excavation, or declivity, are armed with teeth. In common with both *I. typographus* and *I. amitinus*, *I. cembrae* has four teeth on each side of the declivity, the third from the top being the largest. These three species can be distinguished by the following brief key, after Balachowsky (1):

1. Surface of declivity shining, densely and very coarsely punctate. Striae

composed of large, deep, quadrangular punctures, almost contiguous; 3rd tooth of the declivity knobbed in the male, usually similar to the others in the female. . . . . 2.

Surface of declivity mat, soapy, and finely, regularly, and sparsely punctate. Frons granular, with a very prominent tubercle on a level with the clypeus in both sexes. Teeth on the declivity equidistant, 2nd from base widened, 3rd strongly knobbed in both sexes and larger than the others. 4·2–6 mm. . . . . *Typographus.*

2. Antennal club with undulating sutures; both sexes without tubercle on frons, which is entirely and coarsely granular. Small piliferous granules ornamented with long yellow setae, regularly or irregularly spaced, present along suture of declivity and extending to top of declivity. 4–4·2 mm. . . . . *Cembrae.*

3. Antennal club with definite straight sutures; male with flat, lentiform tubercle on frons; female with frons entirely granular, without tubercle. Piliferous granules present along suture of the declivity only at the base or on the anterior third. 3·5–4 mm.. . . . . *Amitinus.*

As has previously been stated the usual host for *I. cembrae* is *L. decidua* Mill. but the beetle is also recorded breeding, on occasion, on *L. sibirica* Iebed (11), *L. leptolepis* Sieb. and Zucc. (8), *Picea* (4, 11, 6), and *Pinus* spp. (1). *I. cembrae* is most usually regarded as being a secondary although important pest of larch, and drought conditions are said to favour epidemics, particularly on poor dry sites.

Felled logs, windblown stems, and standing trees provide sites for breeding. The gallery patterns are stellate, with from two to five mother galleries, the usual number being three or four. These give rise to fairly short larval tunnels terminating in the usual pupal chamber. Normally there are two broods per annum, the first arising from egg-laying in the spring and producing adults in August and September, and the second generally overwintering and the adults emerging in April and May. Maturation and regeneration feeding takes place either as an extension of the galleries in the bark where breeding is located or, somewhat similar to the activities of *Myelophilus* on pine or of *Scolytus* on elm, in short tunnels cut in the shoots of the host tree. Hibernation takes place either in the brood system or in the soil.

PRESENT STATUS IN BRITAIN

The most probable way in which this species entered the country appears to be on the consignments of German timber, previously referred to, which were brought into a number of ports in north-east Scotland in the period 1946 to 1948 and distributed to sawmills throughout that region. Then, *I. cembrae* may have passed undetected or have been confused with *I. amitinus* or *I. typographus*. Since that time it could have maintained itself at a low population level in larch crops; or it could have existed solely in the sawmills on a succession of logs which, as has already been stated, are capable of supporting both the breeding and feeding activities of this beetle. The presence of much windblown larch in

the area coupled with the summer drought conditions of 1955 may then have combined to bring this species into prominence.

If this theory is accepted it is most curious to note that the intensive bark beetle sampling surveys of 1953 and 1954 (2) failed to reveal the presence of *I. cembrae* in blown woodlands in the region where it is now known to be established. Admittedly these surveys were directed mainly towards ascertaining the status of *Myelophilus* on pine, but in their course many samples of larch were also examined for bark beetles. The present data, however, suggests that *I. cembrae* has been present in some of these blown woodlands for at least two years since some of the tunnelled shoots examined had been attacked before 1955.

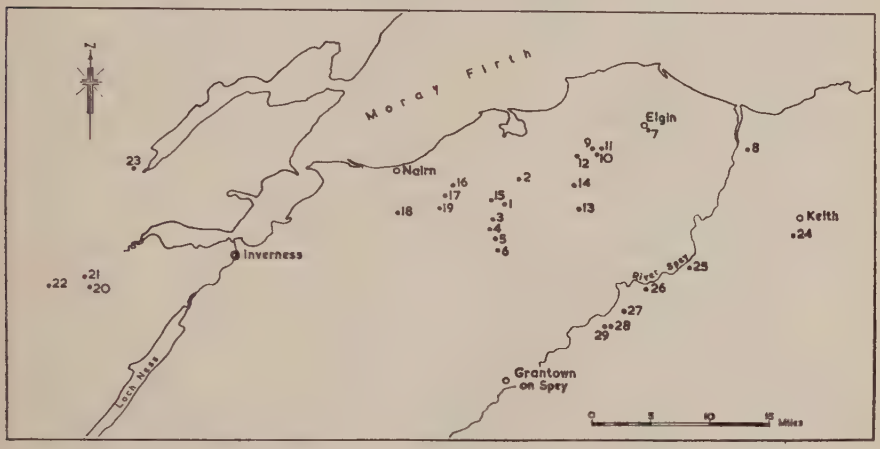

FIG. 1. Distribution of *I. cembrae* ascertained by survey in 1955.

Distribution. The map (Fig. 1) shows the distribution of *I. cembrae* as ascertained by the survey carried out in September–October 1955. Full details of the areas are given in the table.

The distribution records are based on the finding of breeding specimens and/or of twig boring in the characteristic form defined below, and shown in Fig. 2. It was necessary to define the characteristic form of twig boring since it could not be assumed that all broken larch twigs with a bore hole in the broken end were attributable to *I. cembrae*. Twigs broken solely by mechanical agencies are easily distinguishable; and the bore holes of *Argyresthia* and *Pityogenes* are smaller than those produced by *I. cembrae*; but in some cases confusion arose with twigs tunnelled by *Myelophilus* spp. With the high levels of population of *Myelophilus* now present in north-east Scotland following upon the damage to woodlands of the destructive gale of 31st January 1953, conifers other than pine are frequently being used for shoot feeding by the pine shoot beetles. During the survey bored shoots of Douglas fir *Pseudotsuga taxifolia* Rehder, Norway spruce *Picea abies* Karst, Sitka spruce *P. sitchensis* Carr, and *Larix* spp. were found and attributed to *Myelophilus* feeding. Live *Myelophilus* were found in both Douglas fir and Norway spruce shoots and dead, resin-trapped *Myelophilus* in larch shoots. Accordingly,

TABLE: *Details of localities in north-east Scotland from which I. cembrae has been recorded*

County	*Forest or estate*	*Wood or Compartment*	*1" O.S. sheet and reference*	*Locality no. on map*	*Species*	*Age*	*No of damaged shoots/100 sq. yds.*		*Wind-blow in crop*	*General*
							current	*previous*		
Moray	Altyre	Cowgreens	28 029520	1	SP/EL	*c.* 80	68 239	– 5	+	*I. cembrae* breeding in windblown logs.
,,	,,	Stoneyford	28 046556	2	SP/EL	*c.* 80	450	–	+	*I. cembrae* breeding in windblown logs.
,,	Logie, Relugas and Dunphail	Peat-Hillock	28 012500	3	SP/EL	*c.* 45	967	–	+	*I. cembrae* breeding in windblown stems and logs, and in standing trees.
,,	,,	Carnac	28 010489	4	Young EL scattered older EL	*c.* 8 *c.* 40	–	–	–	Nearest windblow ¼ m. to w. Fairly heavy twig fall under old trees, some damage to young crop.
,,	,,	–	38 017474	5	EL/NS EL/SP	*c.* 100 20	8 2	–	+	No breeding galleries present. Slight shoot tunnelling damage.
,,	,,	–	38 018463	6	EL/SP	25	–	–	+	Adjacent to windblow. A few only bored twigs found.
,,	Elgin town	Sawmill	29 222621	7	in yard EL/SP, &c.					Breeding galleries in EL and SP logs which had been in yard for over 1 year.
,,	Speymouth	208	29 357598	8	HL/EL	30	–	–	+ Slight	No breeding galleries present. 3 HL and 4 EL twigs found.
,,	Monaughty	6	28/29 148599	9	EL/JL/SP/DF/NS	25	EL 9 JL 17 EL 1 JL 5			Breeding galleries numerous in EL pit-props in adjacent dump, and on one dead standing EL.
,,	,,	77	28/29 154584	10	HL	27	–	–	–	4 tunnelled twigs found. No breeding.
,,	,,	87–89	29 166600	11	EL/SP/NS/SS/DF	30–40	–	–	+ Scattered	Light twig damage throughout. Breeding in stacked props at rideside.
,,	,,	37	28 126589	12	EL/SP	35	–	–	+ Scattered	No breeding although props stacked there for 1 year. 4 tunnelled shoots found.
,,	Dallas		28 123517	13	EL/SP	50	–	–	+	A few tunnelled twigs found.
,	,,		28 123546	14	ELSP NS	30	–	–	–	A few tunnelled twigs found.

Moray	Darnaway*	—	28 012528	15	EL/SP	25	—	—	+	1 twig containing *I. cembrae* adult found on brief visit.
Nairn	Cawdor	—	28 962544	16	SP/EL	*c.* 60	8	—	+	Windblow cleared by Nov. 54. No breeding.
,,	,,	Crachies	28 951532	17	SP/EL	60	—	—	+	Breeding galleries present in SP and EL.
,,	,,	The Ord	28 886507	18	EL/SP/ NS/DF	80	2	—	+	No breeding, and only few twigs found.
,,	Lethen	Miss Helen's Wood	28 945515	19	EL/SP	50	38	—	+	Breeding galleries present.
Inverness	Beauly	Cragganmore	37 475406	20	EL/SP	60	8 19	— —	—	No breeding galleries found.
,,	,,	—	37 465418	21	EL and hardwoods	75	—	—	—	A few tunnelled twigs found.
,,	Erchless	East castle avenue	37 416408	22	EL	200	—	—	—	A few tunnelled twigs found.
Ross	Brahan	Tollie	27 534565	23	EL/SP and hardwoods	100	—	—	+	A few tunnelled twigs found.
Banff	—	Caird's Hill	29/30 423475	24	SP/EL	60	2	—	+	A few tunnelled twigs found.
,,	Craigellachie Town	Sawmill	39 283433	25	EL/SP &c.	—	—	—	—	Breeding galleries found.
,,	Carron	Drum Wood	39 225406	26	EL/SP	—	22	—	+	Breeding galleries in logs and broken stems. Feeding damage in remnants of crop and adjoining 14-year-old EL.
,,	Ballindalloch	Clachnagour	39 192375	27	EL/SP	95	—	—	+	A few tunnelled twigs found.
,,	,,	Cragganmore	39 175354	28	EL/SP	—	—	—	+	A few tunnelled twigs found.
,,	,,	Nr. above	39 178357	29	EL/SP	100+	—	—	+	A few tunnelled twigs found.

In addition to the above definite records in the counties listed, the survey also embraced larch woodlands in Aberdeenshire, Kincardineshire, Perthshire, the southern counties of Scotland and the northern ones of England without, however, any evidence of *I. cembrae* being found.

* Darnaway Compartments 40 and 45. Breeding in felled and standing trees in 30-year-old European larch in May 1956.

all records and specimens have been carefully scrutinized to ensure that no cases of *Myelophilus* attack have been erroneously ascribed to *I. cembrae*.

Forest Status. The main breeding centres of *I. cembrae* are in windblown or felled stems in the forest and in sawmill logs. In one locality the beetles bred in and killed a number of standing trees, the remnants of a blown middle-aged European larch wood. In many cases the trees so attacked had very small crowns but some other lusty individuals, with well-developed crowns, were also colonized. The drought conditions of the 1955 summer doubtless contributed to the success of the beetle invasion of these stems, and it was interesting to observe that on some trees breeding had been possible only on the southern exposed aspects of the stems where cambial scorch was operative and not on the northern shaded aspects.

During the course of a thinning commenced in May 1956 in compartments 40 and 45 of the Darnaway Estate, *I. cembrae* was observed to be present in large numbers. In this approximately thirty-year-old European larch crop breeding was taking place not only on felled material but also on standing trees. At the time of an inspection in June 1956 it appeared probable that the attacks on standing trees would result in the death of some of them.

Breeding was recorded mainly on European larch and, on two occasions, on Scots pine. On larch, breeding takes place freely both in thick barked material and in small logs, of down to 3 inches in diameter, with thin bark. Patterns with two or three mother galleries were most common, as opposed to the three or four usually found on the continent (Fig. 3). Under uncrowded conditions the mother galleries may be long, up to 8 or 9 inches in length, but in dense infestations they and the larval galleries are cramped, shortened, and distorted.

The shoot tunnelling feeding activities of the beetle can produce serious crown damage in standing crops. After attack, the shoots break off, assisted by wind action, and crown pruning therefore results. The characteristics of these bored twigs are:

(i) That the age of the twig at the point of attack and breakage is at least 2 years and usually more. Six years is quite common and in one case the age at the point of breakage was 18 years, although this was a slowly grown branch. The overall length of the fallen sprays varies from about 9 to 24 inches.

(ii) That the tunnels, which can measure up to 2 inches in length, are generally bored on one side of the twig, just beneath the bark, forming a groove in the wood and leaving a fairly thin cover of bark to the exterior. The tunnels may be straight or follow an irregular or spiral course.

(iii) That the exit hole, where one exists, characteristically occurs in the angle between a dwarf shoot and the main axis, or between two long shoots. Since every twig does not show an exit hole it is probable that some beetles leave the tunnel by the broken end after the twig has fallen, or by the entrance hole before it does so.

This type of twig-boring, crown pruning damage occurs on European larch, Japanese larch, and Hybrid larch, *Larix eurolepis* Henry. Attacks on European larch have been found to be most common, since it is amongst crops of this species

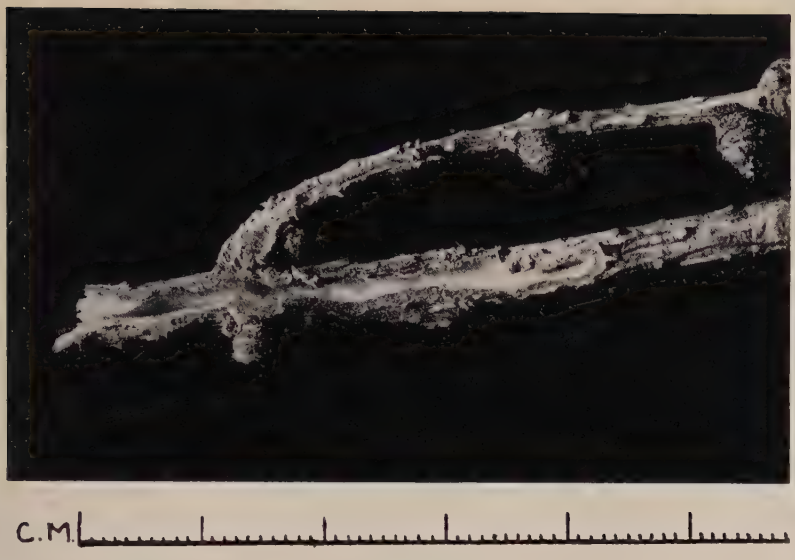

Fig. 2. Feeding tunnel of *I. cembrae* in European larch twig. Bark removed to reveal tunnel.

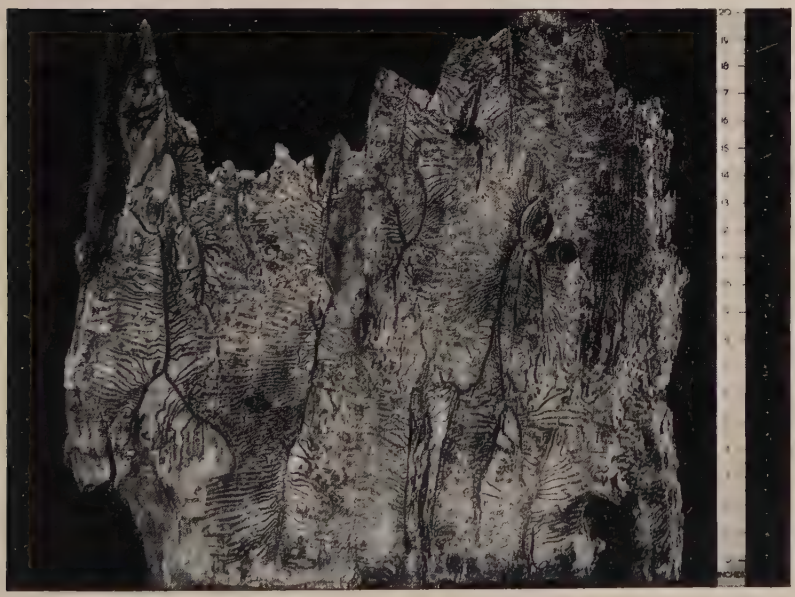

Fig. 3. Inner surface of bark from European larch stem, showing breeding galleries of *I. cembrae*.

PLATE II

that the predisposing factor of windblow is most frequently present, and both young and old crops (8 to 200 years of age) support the feeding activities of the beetle. A rough estimate of the scale of shoot-boring damage was obtained at each survey site by examining and counting all the fallen twigs on a sample plot measuring 10 yards by 10 yards or, in areas of higher infestation, on a plot measuring 5 yards by 5 yards. The indices of number of shoots damaged and fallen per 100 square yards are presented in the table. From this it will be seen that the highest index of infestation recorded was 967 shoots per 100 square yards amongst approximately 45-year-old European larch, adjacent to an extensive blow of that species in which breeding was common, in the Peathillock Wood, Logie Estate, Morayshire. In view of the large size of the individual twigs lost to the tree by these feeding activities, attacks on the scale of that quoted above must be regarded as serious to the crop.

Control. In view of the already fairly widespread distribution of the species and its relatively high numerical status in some areas it must be accepted that there is no possibility of eradicating this recently established and damaging forest insect from Britain. Any control measures which are put into operation, therefore, must be directed towards mitigating the more serious effects of attack by reduction in population numbers. The problem is not dissimilar to that of controlling *Myelophilus* in pine crops and in general the normal methods practiced against *Myelophilus* such as the maintenance of forest hygiene; the timing of thinning, felling, and extraction operations adversely for breeding; the barking of logs to prevent or to eliminate infestation; and the use of trap logs and stems, can be recommended.

ACKNOWLEDGEMENTS

The authors have pleasure in acknowledging the co-operation of Mr. R. T. F. Larsen, the local forest officer who made the original find at Monaughty; and of Messrs. K. A. Longman and D. W. Henman who independently observed the shoot tunnelling behaviour of *I. cembrae* shortly after the date of the original record and who subsequently carried out the field survey referred to in this paper.

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I.U.F.R.O., OXFORD, 1956

The 12th Congress of the International Union of Forest Research Organizations met at Oxford under the Presidency of Professor Aldo Pavari of Italy from the 7th to the 14th July 1956 and was opened by the Minister of Agriculture, Mr. Heathcoat-Amory. The Congress was attended by nearly 250 delegates, mainly European, but also including Canada, Australia, New Zealand, India, America, Russia, Korea, and Japan. It was the first time that the Union had met in Britain.

The principal subject sections and their leaders are given below.

General: Bibliography. Professor E. Saari, University of Helsinki.

General Forest Influences: Professor Sir Harry Champion, Imperial Forestry Institute, University of Oxford.

Forest Production, Establishment and Maintenance of Forests:

Research on Site Factors. Professor A. de Philippis, University of Florence.

Study of Forest Plants. Dr. C. Syrach Larsen, Director, Horsholm Arboretum, Denmark.

Silviculture. Professor H. Leibundgut, Director, Institute of Silviculture, Zurich.

Forest Protection. Dr. H. van Vloten, Director, Forest Research Station, Wageningen, Holland.

Study of Growth and Yield and of Forest Management. Professor Y. Ilvessalo, F. R. Institute, Helsinki.

Forest Economics—Operational Efficiency:

Forest Economics. Professor J. Speer, Professor of Forest Economics, University of Munich.

Operational Efficiency. Professor U. Sundberg, F. R. Institute, Stockholm.

Forest Products: Mechanical Conversion: Chemical Conversion. M. J. Campredon, Director, Institute National du Bois, Paris.

Visits were arranged during the first week to the Forestry Commission Research Station at Alice Holt Lodge, The Forest Products Research Laboratory at Princes Risborough, and the Rothamsted Agricultural Experimental Station, while for the second week, seven tours were arranged. Three tours were in England, three in Scotland and one in Wales.

The next Congress is to be held in Vienna at a date still to be fixed.

Mr. James Macdonald, Director of Research and Education, Forestry Commission, Great Britain, was elected President in succession to Professor Pavari, Italy, and Dr. H. van Vloten, Netherlands, was elected Vice-President.

VARIATION OF DENSITY IN THE WOOD OF *PINUS PATULA* GROWN IN KENYA

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AND

L. CHALK

(*Department of Forestry, University of Oxford*)

SUMMARY

1. The specific gravity was determined for the individual rings of twenty-three 13-year-old stems of *Pinus patula* grown in Kenya and also separately on the early and late wood of six rings.

2. Significant correlations were found between specific gravity and both ring width and age of the ring from the pith. The effect of ring width was slight with more than six rings to the inch.

3. A comparison with Turnbull's data from South African trees of the same species confirmed his results only in the first nine rings from the pith.

4. The mean specific gravity of the early wood in five rings was 0·368 compared with 0·469 for the late wood. This high value for the early wood and the small difference between early and late wood was due to the thickness of the walls in the early-wood tracheids. Similar thick-walled early-wood tracheids were observed in Kenya species of *Juniperus* and *Podocarpus*.

INTRODUCTION

IF there were any simple solution to the problem of whether conifers could be grown fast without seriously decreasing the quality of their timber, it would probably have been found many years ago, as the subject has been under almost continuous investigation since the time of Robert Hartig and earlier. Yet the subject raises as much controversy today as at any other time, possibly because a definite answer becomes more urgent as the growing of exotics on short rotations becomes more economically desirable.

The more recent and important papers on the subject have been admirably analysed by Spurr and Hsiung (5) and there has been a lively correspondence recently in the *Quarterly Journal of Forestry* (1, 2). The most serious challenge to the classical view that density is inversely proportional to ring width came from the work of J. Turnbull in South Africa, carried out principally on *Pinus patula* Schlectendal and Chamisso. This work was brought together in a paper discussed at the British Empire Forestry Conference in London in 1947 (6). Turnbull's thesis was, very briefly, that density increases outwards from the pith in proportion to the age or number of rings from the pith. As ring width nearly always decreases in the same direction, there appears to be a relation between narrow rings and high density, but this relation is purely accidental, as is shown by the persistence of this tendency for density to increase outwards, even in trees in which the ring width increases outwards from the pith.

This hypothesis was so much at variance with current ideas and the observations of other investigators, particularly in the Northern Hemisphere, that it was tempting to assume that there must have been some special conditions that would render these results inapplicable in a more general field. The only obvious conditions that might conceivably have come into this category were those induced by the heavy thinning techniques of Craib, designed to avoid root competition at any stage, but these did not provide a very convincing explanation. It was thought, therefore, that it would be of interest to make an independent study of the same species grown under different conditions, and material was collected for this purpose by one of the authors from a plantation of *P. patula* in Kenya. Statistical analysis of the results showed that both explanations are correct—that there are significant relations between age and density and between ring width and density, though it seems likely that their relative importance may change during the life of the tree. Studies of individual rings and of the changes in cell size and wall thickness, however, supplied a hint that the conditions of growth may represent a special case after all. It was found that the wall thickness and density of the early-wood tracheids was comparable to that of the late wood of many European conifers and that there was only a small difference between the early and late wood. The particular interest of this lies in the observation of similar thick-walled early-wood tracheids in indigenous East African species of *Juniperus* and *Podocarpus*.

MATERIAL AND METHODS

Material. Specimens of *Pinus patula* were obtained from a routine thinning in May 1955 of Plantation Kitiro 3e in the Elburgon Forest District. The crop was planted in 1941, pruned in 1945 and 1946, and pruned and thinned in 1949–50. Disks were cut at 1 foot above ground-level from thirty trees, and brought to Oxford for examination.

Growth rings and rainfall. Temperature in the Kenya climate is never a limiting factor to growth and the visible limits of growth rings are formed during the onset of dry conditions. The Silviculturist, Kenya, has reported on pruning-occlusion experiments in the same area that there is continuous, but fluctuating, growth for at least 10 months of the year. Usually the rings are clearly defined by the comparatively sharp outer boundary of the late wood. Some of the growth rings, however, showed a double structure, the late wood being divided into two zones separated by a narrow band of early thinner-walled tracheids. In these rings the first zone of late wood has only vaguely defined boundaries with the thin-walled tracheids on either side. In such cases the end of the growth ring was taken to be the sharp outer boundary. A check on the dating of the growth rings was provided by the exceptionally wide ring of 1947 and the double zone of late wood in 1951, both of which were easily recognizable in all the samples. The width of the rings was measured across the diameter of least eccentricity.

Specific gravity determinations. A strip of wood approximately 1 inch wide was removed from each disk along the diameter selected for the measurement of ring width and trimmed to a depth of about 2 inches. Blocks were split off along one

radius of this for determining the specific gravity, a separate block for each growth ring; the 'specific gravity' was calculated from the ratio of oven-dry weight to saturated volume. In some cases two or three growth rings had to be combined because of the narrowness of the rings and the difficulty of separating them accurately.

The blocks were soaked in water under vacuum until they sank when restored to atmospheric pressure. The volume was obtained by suspending the block in one of two balanced beakers and measuring the weight necessary to restore the balance. The blocks were then dried in three stages, an overnight exposure in the laboratory, 12 hours in an oven at 60° C., and finally in an oven at 105° C. The oven-dry blocks were highly hygroscopic and special precautions were taken to make the time between removal from the oven and the completion of weighing as short and as uniform as possible. A correction was applied, based on the time interval and the size of the block.

A second series of specific-gravity determinations was made on six growth rings in each of which the early and late wood were split off into separate blocks. Owing to the small size of these blocks, particularly those of the late wood, the volume was obtained from the difference between the weight in air and the weight in water.

Dimensions of cells and cell walls. Measurements of the changes of dimensions of cell walls, cell lumina, and cell diameters throughout the growth ring were made by means of a Shand micrometer, the sections being viewed under a microscope with a 1/6 objective and a No. 4 eyepiece. This instrument is essentially a mechanical stage that can be moved in one direction by either of two micrometer screws. It is thus possible to traverse any required distance or number of cells and to read off separately the total width of the walls traversed and the total width of lumina. For this investigation readings were taken every ten cells across the growth ring and three complete traverses made in different parts of each ring. As far as possible lines were selected that traversed tracheids cut through in their wider central portions and the narrow tips avoided.

RESULTS AND DISCUSSION

Growth rings and rainfall. Seven disks, out of the thirty available, were discarded on account of marked eccentricity or signs of mechanical injury. The ring widths for ten trees are illustrated in Figs. 1 A and B and it will be seen that from 1947 onwards, that is after the trees were 5 years old, the pattern of annual variation is very similar in all the trees. The mean widths for all the trees are plotted in Fig. 1C, together with the annual rainfall. As January and February are almost invariably dry, the annual total corresponds very closely with the rainfall during the growing season. From 1947 onwards there is a close correlation between the curves. The chief exception is the year 1949, when the increase in the rainfall is not matched by an increase in ring width. This can probably be explained in terms of thinning, which did not take place until late 1949 and early 1950. As a result ring width may have been restricted by root competition during the 1949 growing season.

Specific gravity of the wood. The specific gravities of the individual rings are shown in Fig. 2, plotted against age (number of rings from the pith). In some instances, as has been explained above, it was necessary to combine two rings in one block; these samples are distinguished in the figure by being marked as

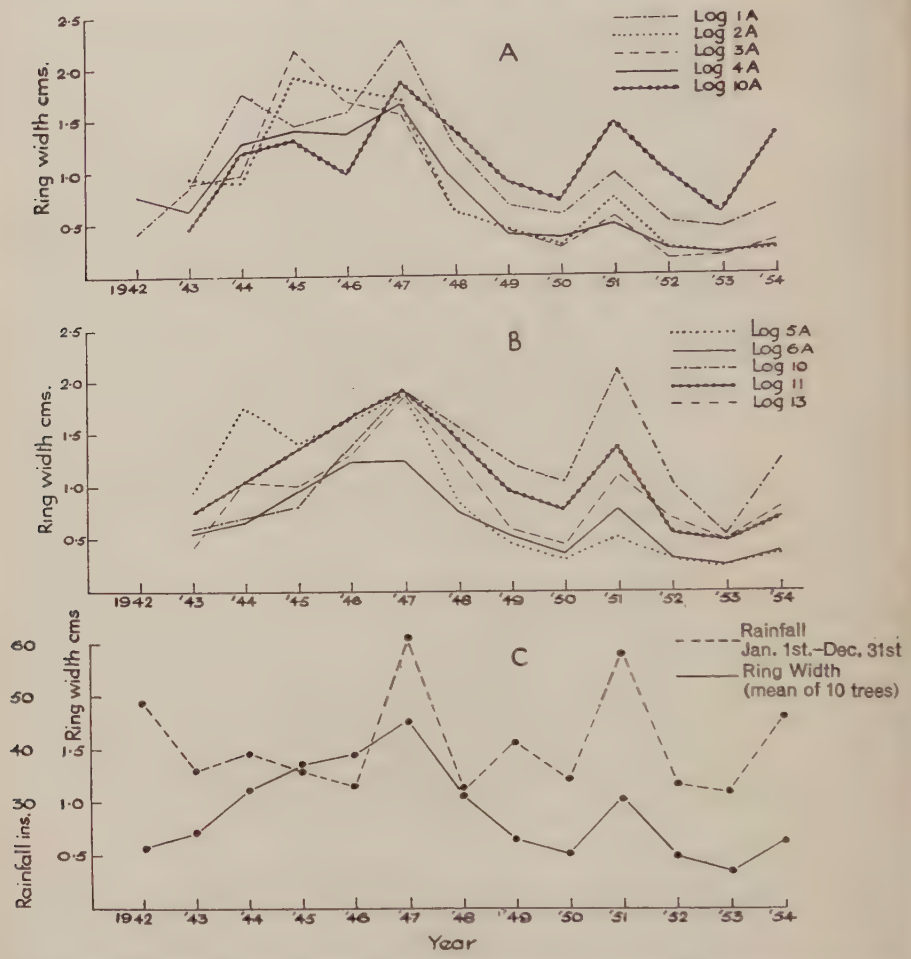

Fig. 1. Ring widths and rainfall. A and B. Ring widths in individual logs. C. Mean ring widths and rainfall for successive years.

crosses. This figure well illustrates the difficulty of demonstrating a relation between specific gravity and either age or ring width. In the figure there is a general trend for specific gravity to increase outwards from the pith, but it must be remembered that in Fig. 1C there was a decrease in ring width outwards, at any rate from 1947 onwards. If specific gravity is plotted against ring width, as in Fig. 3, there is a clear trend for specific gravity to be higher in the narrower rings, but then the narrower rings are also those farthest from the pith. In addition, it was found that though there was a close relation between specific gravity and

ring width for the years 1947 and 1951, there appeared to be none for 1946 and 1948.

When it became apparent that graphical methods would not give a clear-cut relation between either age or ring width a multiple-regression analysis was made

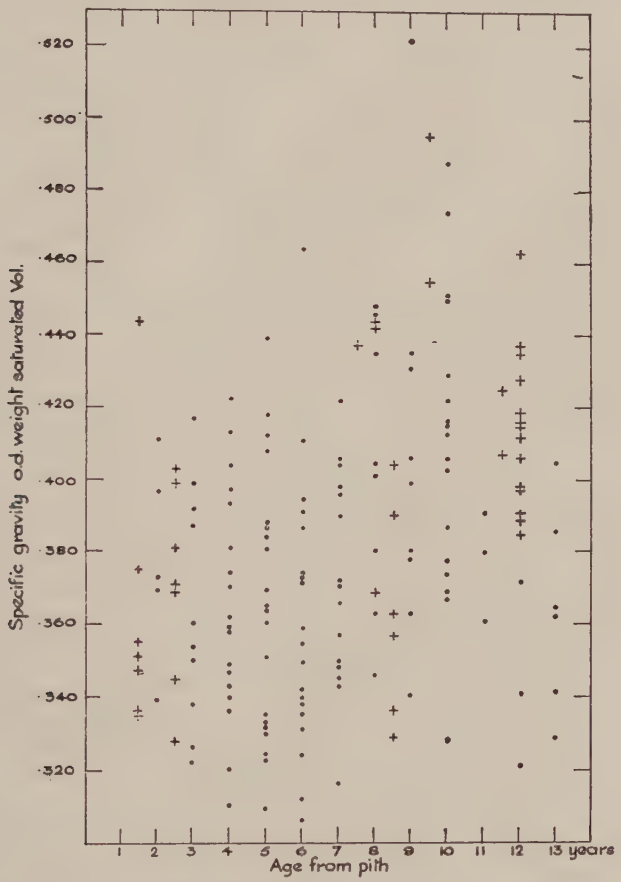

FIG. 2. Specific gravity and age from pith. Crosses indicate blocks that included more than one growth ring.

involving the factors of age and ring width. The data and computations yielded the equation below:

Estimated $y = 0{\cdot}395 + 0{\cdot}002448x - 0{\cdot}03029z$,

where y = density in g./c.c. at zero moisture content,
x = age in years from the pith,
z = ring width in centimetres.

Table I shows that although only 25 per cent. of the sum of squares is removed by the regression it is nevertheless highly significant.

In an endeavour to find the relative importance of the two factors, age and ring width, the sum of squares removed by each factor was determined. Table II

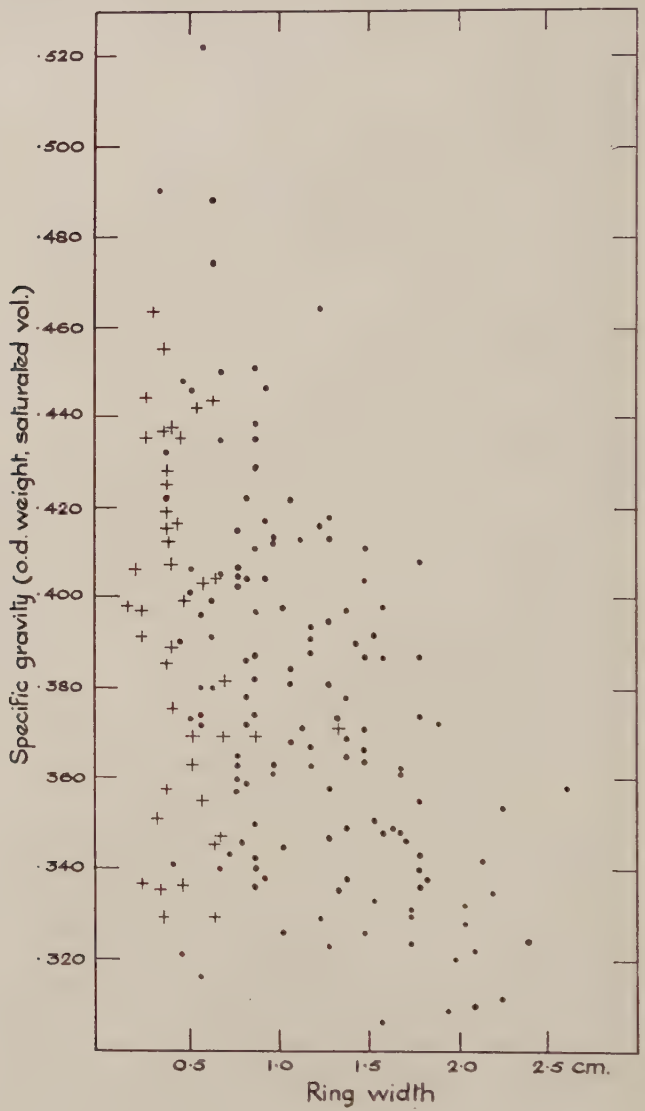

Fig. 3. Specific gravity and ring width. Crosses indicate blocks that included more than one growth ring.

shows that although ring width is the more important factor in the regression the effect of age is highly significant.

The equation was used to estimate specific gravities for varying ring widths at 0, 10, and 20 years from the pith. For convenience, ring widths have been expressed as rings per inch and the calculated specific gravities have been converted

TABLE I. ANALYSIS OF VARIANCE *showing significance of regression*

	Degrees of freedom	*Mean square*	*Variance ratio F.*
SUM SQUARES DUE TO REGRESSION $= b\sum(x-\bar{x})(y-\bar{y}) + c\sum(z-\bar{z})(y-\bar{y})$ $= (0{\cdot}002448)(8{\cdot}7971) + (-0{\cdot}03029)(-1{\cdot}9133)$ $= 0{\cdot}0215 + 0{\cdot}580 = 0{\cdot}0795$	2	0·03975	32·64*
Residual s.s. = 0·2228	183	0·0012175	
Total s.s. $\sum(y-\bar{y})^2 = 0{\cdot}3023$	185	..	..

* Significant at 5% level.

TABLE II. ANALYSIS OF VARIANCE *showing significance of each factor*

	Degrees of freedom	*Mean square*	*Variance ratio F.*
s.s. due to regression on z (ring width) = 0·0696 .	1	0·0696	57·17*
s.s. due to regression on x (age) . . = 0·0099 .	1	0·0099	8·13*
Residual sum squares . . . = 0·2228 .	183	0·0012175	..
Total . . . . . 0·3023 .	185	..	..

* Significant at 5% level.

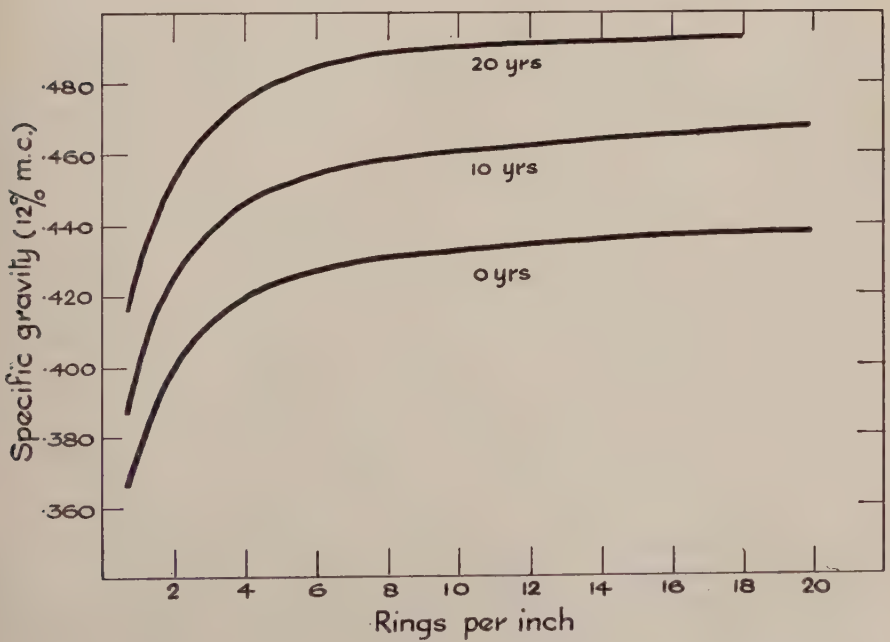

FIG. 4. The effect of age and of growth rate on the density of the wood of *Pinus patula*.

to 12 per cent. moisture content. The results are given in Fig. 4, from which two points of interest emerge. Firstly, each 10-year increase in age from the pith is accompanied by an increase in specific gravity of 0·027; and, secondly, with decreasing ring width the density increases, steeply up to 4 rings to the inch, less steeply from 4 to 8 rings to the inch and above 8 rings to the inch the increase is very slight.

The equation was next used on Turnbull's data (6), to compare specific gravities calculated for his ring widths and ages with the figures actually observed by him. In Fig. 5 Turnbull's results are shown on the left. On the right are the values calculated according to the equation derived from the Kenya data. A slight alteration has been made to Turnbull's original illustration by expanding the horizontal scale. It can be seen that for rings 6–15 the pattern obtained in each of the two sets of figures (A and B) is remarkably similar. It will be noted, however, that in the eleventh and fourteenth years the equation produces a reduction in specific gravity, whereas Turnbull's results show a continuous increase. It is suggestive that in both Turnbull's and the calculated specific gravities over this 9-year period the greatest increases with age occur where there is a decrease in ring width.

For rings 17–22, however, there is no such similarity in pattern between the actual and calculated specific gravities, as will be seen in Fig. 5 C and D. In comparing the patterns it should be noted that Turnbull's results do not, over this range, agree with his hypothesis of a consistent increase in specific gravity with age from the pith.

Specific Gravity of Early and Late Wood

The specific gravities of the early wood and the late wood were determined separately in six rings. The results are given in Table III. One pair of results

TABLE III. *Specific gravities of early and late wood*

Sample no.	*Early wood sp. gr.*	*Late wood sp. gr.*
1	0·382	0·418
2	0·353	0·477
3	0·356	0·528
4	(0·483)	(0·559)
5	0·367	0·450
6	0·381	0·472
Mean (omitting no. 4)	0·368	0·469

(no. 4) was abnormally high and suspected of containing compression wood, and was therefore disregarded when calculating the mean.

Although there is considerable variation in the figures for both early and late wood, it is similar to that found by other workers. The observations of Paul (3) on southern pines are given below for comparison.

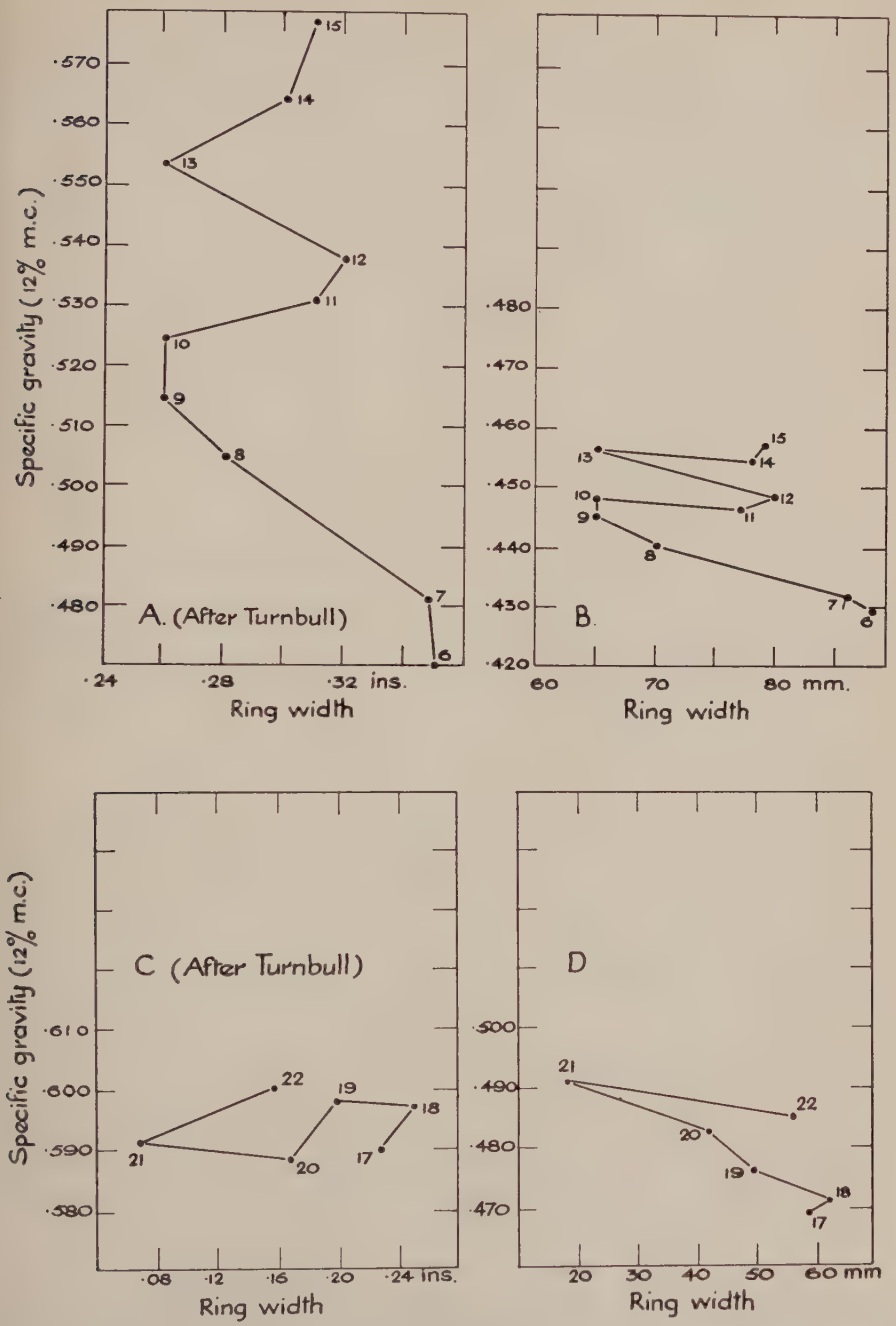

FIG. 5. A comparison of the density pattern in successive rings. A and C as observed by Turnbull, B and D as calculated by equation derived from the Kenya material. The numbers against the points indicate the number of the ring, counted from the pith.

The figures in Table IV show that in the southern pines the ratio of specific gravity of the late wood to that of the early wood is more than 2·0. This is in marked contrast with the ratio of 1·2 for the Kenya *P. patula*, which is suggested as a possible explanation for the lack of any clear-cut relation between ring width and density in this species. Using the data in Tables III and IV and assuming a

TABLE IV. *Specific gravities of early and late wood in southern pines* (from Paul, 3)

Species		*Range of 75% of observations*	*Mean*	*Ratio late wood/ early wood*
Slash pine:	early wood	0·21–0·33	0·275	2·07
	late wood	0·38–0·70	0·570	
Shortleaf pine:	early wood	0·21–0·33	0·267	2·28
	late wood	0·36–0·74	0·600	
Loblolly pine:	early wood	0·25–0·36	0·310	2·01
	late wood	0·44–0·72	0·625	
Longleaf pine:	early wood	0·22–0·32	0·280	2·46
	late wood	0·61–0·79	0·690	

constant width of late wood, it is possible to calculate the effect of doubling the width of the ring on the proportion of late wood and so on the specific gravity. Assuming a constant width of late wood of 0·1 cm., doubling the ring width from 0·5 to 1·0 cm. would give an increase of about 0·03 in the specific gravity of Slash pine, but of only 0·01 in *P. patula*.

Dimensions of Cells and Cell Walls

Following the discovery of the close similarity between the specific gravities of early and late wood in *P. patula* it was logical to seek an explanation in terms of the structure of the wood, particularly in terms of wall thickness and cell size. Two rings, each from a different log, were selected, namely the 1949 ring from Log 18 and the 1951 ring from Log 15. The changes in the radial width of the cells from the beginning to the end of the ring are shown in Fig. 6. In the 1949 ring there is a gradual, but well-marked, decrease in cell size throughout the ring. In the 1951 ring there is very little change throughout the ring except at the very end. This appears to be due to a period of increasing cell size towards the end of the ring that disturbs the pattern of a steady decrease. Measurements of wall thickness and radial diameter of the lumen are shown in Fig. 7. In general the changes in the size of the lumen follow the same pattern as the changes in cell size, but in more exaggerated form. The reversion in the later part of the 1951 ring to the dimensions typical of the earlier part of the ring is very much more marked. It is notable also that in the 1949 ring the size of the lumen is not at its maximum at the beginning of the ring, but increases up to the 55th cell.

The most interesting figures are those for wall thickness. These are remarkable for the absence of any marked change throughout the ring. The walls are of practically the same thickness at the beginning of the ring, when the diameter of

the lumen is approximately four times the thickness of the wall, as they are in the 135th–155th cells in which the lumen in the 1949 ring has dropped to about the same width as the wall. At this point the 1951 ring shows a decrease in wall thick-

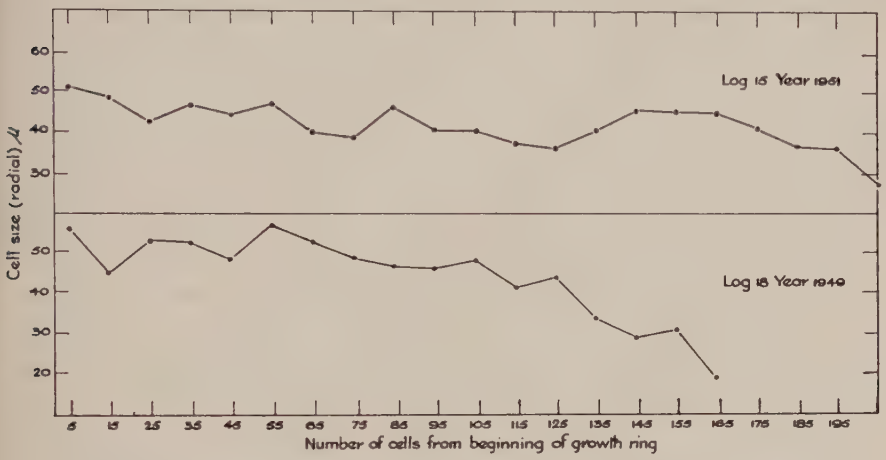

FIG. 6. Variation in cell size (radial) throughout the growth ring in *Pinus patula*.

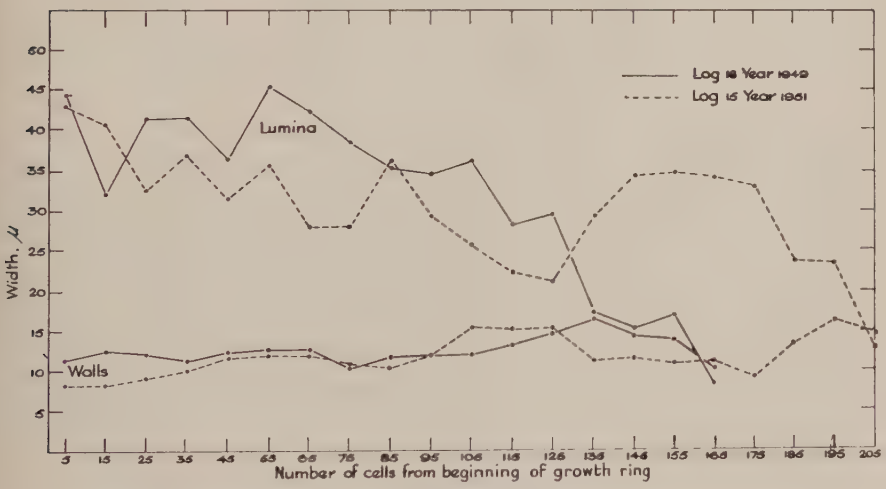

FIG. 7. Variation in wall thickness and radial width of lumen throughout the growth ring in *Pinus patula*.

ness corresponding with the increase in cell size noted above. In both rings the last few cells formed show a decrease in wall thickness.

Perhaps the most suggestive point about this uniformity of wall thickness in *P. patula* lies in the fact that it is due to the occurrence of very thick-walled early-wood tracheids and not to any thinness in the walls of the late wood. A comparison with some European conifers is shown in Fig. 8. Here the wall

thickness of the 1949 ring is compared with that of Scots pine, Sitka spruce, and European larch. It is remarkable that, whereas the European conifers all start the ring with a wall thickness of less than 5 μ, in *P. patula* the walls are more than twice as thick. Indeed the early-wood tracheids of the *P. patula* have walls as thick or thicker than those of the late wood in the European conifers. In terms of wall thickness, therefore, it might be claimed that the ring in *P. patula* is composed entirely of late wood. Smith (4) has suggested defining late wood arbitrarily as having a combined width of two walls and middle lamella that is as great as or greater than the radial width of the lumen. This would go to the other extreme

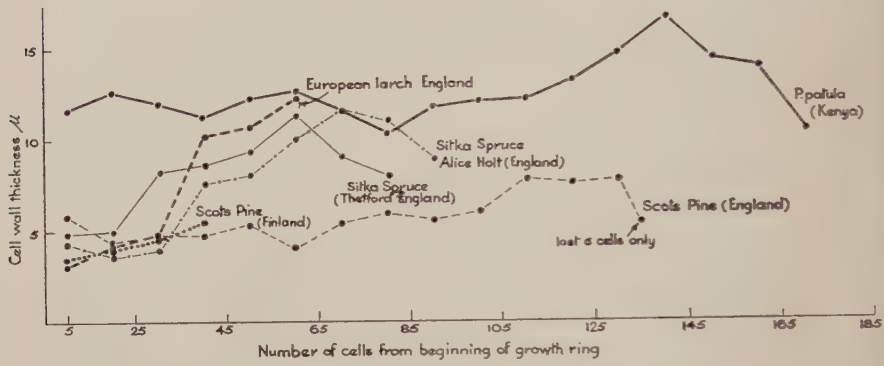

FIG. 8. Comparison of wall thickness throughout the growth ring in *Pinus patula* and with that of European conifers.

and, though separating the early- from the late-formed part of the ring in *P. patula*, would deny the existence of any late wood to some of the European conifers. However, such technicalities are of small importance compared with the fact that the 'early wood' of *P. patula* is comparable in density, and presumably therefore in properties, with the late wood of other species.

Comparative figures for specific gravity can be calculated from these data for wall thickness and cell size, since specific gravity is proportional to the amount of cell wall present. To simplify calculation it has been assumed that the tracheids are rectangular in shape, that the cell wall material is laid on evenly all round and that the tangential dimension of the cells remains constant. With these assumptions, specific gravity is expressed as follows:

$$D\frac{l\times k-\{(l-w)(k-w)\}}{l\times k},$$

where k = the constant dimension in the tangential direction, l = cell size (wall and lumen) in the radial direction, and w = cell wall thickness. Using this expression it is possible to relate specific gravity to the more easily determined ratio of wall thickness to cell size. The relation between this ratio and cell density is shown graphically in Fig. 9 and the changes in cell density across the two rings of *P. patula* are illustrated in Fig. 10.

The data from the Kenya material were compared with data from similar

measurements made on single rings of conifers grown in Europe, including Sitka spruce, European larch, and Scots pine grown in Great Britain and in Finland. The results are shown in Fig. 11. It should be borne in mind, however, that

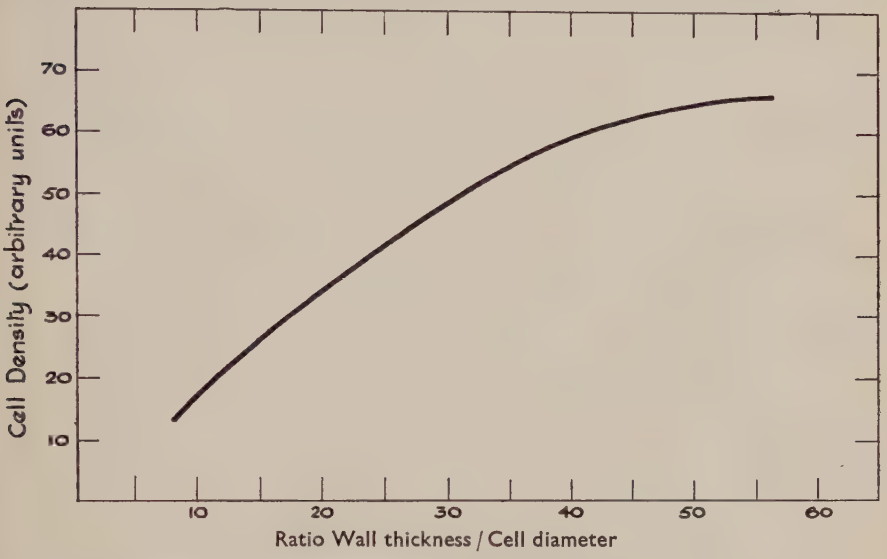

Fig. 9. Variation in cell density with ratio of radial wall thickness to cell diameter.

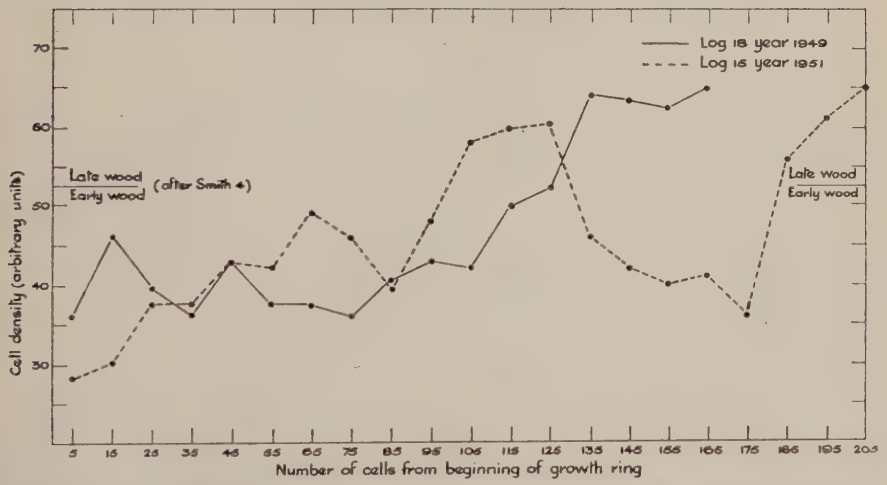

Fig. 10. Variation in cell density throughout two growth rings of *Pinus patula*. The division shown between early and late wood is based on Smith's (4) definition.

abrupt changes in density tend to be obscured by the method of averaging ten cells together and that the assumption that wall thickness is increased evenly round the wall is not always valid. In the Finnish Scots pine, for example, deposition was greatest in the angles of the cell wall (making the lumen round in cross

section) and as a result the calculated density of the late-wood tracheids is probably an underestimate.

It will be seen from Fig. 11 that the increase in cell density from the beginning to the end of the ring is more rapid in the European species than in *P. patula*.

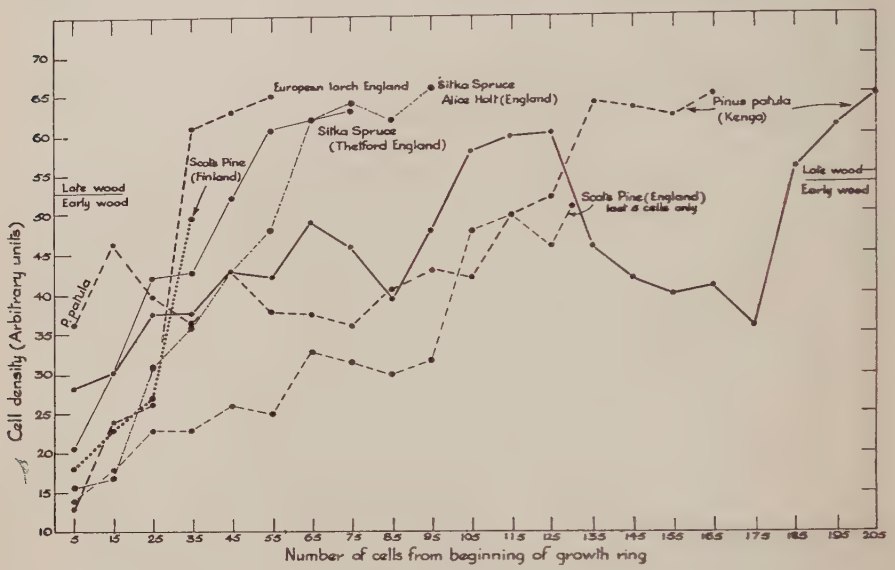

Fig. 11. Comparison of cell density throughout the ring in *Pinus patula* with that of European conifers.

Table V. *The range of cell density in different species*

Species	Cell Density		
	Early wood minimum	*Late wood maximum*	*Early wood as % of late wood*
Pinus patula 1949	36	60	60
P. patula 1951	28	60	47
P. silvestris (Finland)	18	49	37
P. silvestris (England)	14	51	27
Picea sitchensis	16	66	24
Larix europea	13	65	20

The abruptness of the change from early to late wood tends to be obscured by the method of averaging ten cells, but, except in the Sitka spruce, there is a sharp increase in density as the late wood is entered. In the Scots pine and larch the change in density is of the order of 13–32 rising to 48–61 within ten cells. No such sharp increase occurs in *P. patula*. The reason for the evenness of the density in *P. patula* appears to be that the early already has a high density. This can be seen in Fig. 11, but is more clearly shown in Table V. In the third column the calculated density of the first-formed early wood is expressed as a percentage of that

of the thickest-walled late wood. It will be seen that, not only are the actual densities of the *P. patula* early wood appreciably higher than those of the European species, but that there is a much smaller difference between the densities of the early and late wood in *P. patula*. Whereas the density of the early wood in the *P. patula* is about half that of the late wood or more, it is only about one-fifth to one-third in the European woods.

It seemed possible that this difference in structure between the Kenya-grown *P. patula* and the European species might be explicable in terms of the conditions of growth. Two other Kenya conifers—indigenous species—were examined to see if they too exhibit the same peculiarity.

TABLE VI. *Wall thickness of early wood tracheid in species grown in Kenya and in England*

Species	*Country*	*Wall thickness, in mm.*			
		1st 10 cells	*2nd 10 cells*	*3rd 10 cells*	*Last 10 cells*
Pinus patula . . .	Kenya	0·116	0·125	0·120	0·145
Podocarpus gracilior . .	Kenya	0·090	0·096	0·093	0·090
Juniperus procera . . .	Kenya	0·073	0·073	0·070	0·083
Pinus sylvestris . . .	England	0·058	0·043	0·048	(0·075)
Picea sitchensis . . .	England	0·043	0·035	0·040	0·075
Larix decidua . . .	England	0·030	0·042	0·047	0·103
Juniperus virginiana . .	England	0·030	0·050	..	0·050

It will be seen from Table VI that in both *Podocarpus gracilior* Pilger and *Juniperus procera* Hochst the early-wood tracheid walls are distinctly thicker than in any of the European species, though the late wood is no denser. Indeed, the early wood of the Kenya species with a range of 0·073–0·116 appears to be as thick or thicker-walled than most of the late wood in the European species, with a range of 0·075–0·103.

J. virginiana Linn., grown in England, has been added so as to give a direct comparison with the Kenya juniper, the English juniper being too small a plant to make a fair comparison. It will be seen that the early-wood tracheids of the Kenya species have walls that are more than twice as thick as those of the *J. virginiana*.

The most striking difference between the conditions of growth in Kenya and England is probably that the dormant period is one of drought in the former and one of winter rainfall in the latter. Added to this there is some reason to suppose that the renewal of the crown at the beginning of the season is much more marked under North Temperate conditions. In England it is probable that at the beginning of the growing season there is little food material available for wall thickening owing to the demands of the rapidly forming new crown, and conditions of light and temperature are probably not at their optimum for photosynthesis, whereas the development of maximum cell diameter would not be restricted by lack of water. If a plentiful water supply were to be associated with

rapid cell division in the cambium, the lack of material for wall thickening would tend to be intensified. It is therefore of interest to note that the only deciduous species, the European larch, had the thinnest-walled early-wood tracheids and the greatest contrast in density between early and late wood.

Under the Kenya conditions the less marked development of a new crown and the better conditions of light and temperature for photosynthesis by the old crown might well result in there being more food material available for the thickening of the tracheid walls at the beginning of the season. Further, as the dormant period is one of drought, it is reasonable to suppose that the soil moisture available may be insufficient for either a cell diameter or a rapidity of cambial division that is in excess of the amount of food available. Hence wall thickness remains relatively constant and cell diameter decreases only gradually towards the end of the season. Such increase in cell density as there is at the end of the season is due to reduction in the size of the lumina rather than to any increase in wall thickness. The importance of water supply is emphasized by the development of the 1951 ring in *P. patula*. This was a wet year (see Fig. 3) in which a wider ring was produced, apparently as the result of the formation of a zone of slightly lower density wood towards the end of the ring (see Fig. 10, cells 135–75). The reduction in density was due primarily to an increase in the size of the cells and of the lumina (see Fig. 11); wall thickness decreased only slightly.

One curious feature of the 1951 ring of *P. patula* was the occurrence of drought cracks in several of the disks. In view of the higher rainfall in this year, the occurrence of this defect is difficult to explain. It must be remembered, however, that this feature, in spite of its name, is the result of 'collapse', a prerequisite of which is that the cells shall be completely filled with water.

CONCLUSIONS

The results of the investigation into the pattern of density variation cannot be said to refute either of the two most commonly held hypotheses—that variation is determined by (*a*) ring width, or (*b*) age from the pith. On the contrary it has been shown that both factors were operating simultaneously. But it must be emphasized that the material studied was only 13 years old and it is quite possible that one or the other factor might dominate under particular circumstances or at different stages in the life of a tree. In any case there was a special characteristic of the wood of the Kenya *P. patula* that suggests that these results may not necessarily be of general application. This was the unusually dense early wood that is in marked contrast with the early wood of European and North American softwoods. The high density of the early wood and the lack of any marked difference between early and late wood make width of ring and percentage of late wood of relatively little significance in relation to the density of the wood as a whole. It has been shown that this high density of the early wood is due to the thickness of the tracheid walls and the observation that similar, thick-walled early-wood tracheids occur in indigenous Kenya softwoods (*Podocarpus* and *Juniperus*) suggests that the influence of growing conditions on the nature of the early wood and the importance of this tissue deserve further investigation.

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WILLIAM WRIGHT SMITH

Sir William Wright Smith, F.R.S., F.L.S., F.R.S.E., Queen's Botanist in Scotland, Regius Keeper of the Royal Botanic Garden, Edinburgh, and Regius Professor of Botany at Edinburgh University died in Edinburgh on 15 December 1956 at the age of 81.

Born in Lochmaben, he received his early education at Dumfries Academy, entered Edinburgh University in 1891, graduated in 1896, and was thereupon placed in charge of research work in the university department of botany by Sir Isaac Bayley Balfour who then held the Chair of Botany.

Five years later, at Balfour's instigation, he went to Calcutta as keeper of the herbarium in the Royal Botanic Garden and in 1908 was made Superintendent and Director of the Botanical Survey of India. This post gave him the opportunity of exploring the flora of the then almost virgin ground on the confines of Tibet, Sikkim, and Nepal and about the Kangchenjunga country, an invaluable experience shared by few living botanists.

In 1911 Smith returned to Edinburgh as deputy to the director of the botanic garden, and succeeded to the post on Balfour's resignation in 1922. To his lot fell the elucidation of the remarkable collection of plants made in Yunnan, Tibet, and Burma by George Forrest in his later expeditions, a task complicated by the explorer's untimely death in 1932.

He was a vice-president of the Royal Horticultural Society and was the society's Professor of Botany. He was awarded the Victoria Medal of Honour in 1925 and the Veitch Memorial medal in gold for his work on the genus *Primula* in 1929. He published numerous works on Himalayan and Chinese plants, and his most important recent work was on the genus *Primula* undertaken with Dr. H. R. Fletcher.

Smith was made an honorary life member of the American Primrose Society in 1953. He was a D.Sc. of Toulouse and an honorary LL.D. of Aberdeen University. He had been a fellow of the Society of Foresters since 1927.

JOHN STIRLING MAXWELL: AN APPRECIATION

By J. A. B. MACDONALD

SIR JOHN STIRLING MAXWELL, Bt., K.T., of Pollok died at his home within a week of his ninetieth year. He had been severely paralysed since 1940 but still took a very keen interest in everything, and especially in forestry, until the end.

Sir John was a member of the Acland Committee in 1917–19. It was upon their recommendation that the Forestry Commission was set up. Sir John was a Commissioner from the inception of the Forestry Commission and was Chairman for 3 years from 1929 to 1932, retiring then at the age of 65. He joined this Society in 1927, was promoted Honorary Fellow in 1932, and was awarded the Society's medal in 1950 for pioneer work on peat planting. To many of us Sir John is best remembered for this work.

As a young man he bought the 70,000-acre estate of Corrour on the Moor of Rannoch in 1892 and began planting forthwith. He therefore had the unique experience of seeing trees, which he himself had planted, 63 years later. The idea of pioneering in forestry on high peat lands was first proposed by Professor Augustine Henry who suggested that Sir John should go to see the Belgian planting on peat in the Hertogenwald. This visit was made in 1906 and most modern ploughing techniques on peat land are simply a continuation of the pioneering work which Sir John introduced.

Apart from forestry Sir John had very wide interests. He was President of the National Trust for Scotland, Chairman of the Royal Fine Arts Commission, and a member, if not Chairman, of the Ancient Monuments Commission. He was a fine artist and many of his water colours, generally of Corrour or other moorland scenes, appeared at exhibitions of the Royal Scottish Academy and elsewhere. He was also an architect of great distinction. Corrour Lodge, which he himself designed and built at the head of Loch Ossian, was a building of great beauty in Rannoch granite with Rannoch pine panelling throughout. As may be imagined, it was a delightful place for a forester to stay, as I had frequent opportunity to do from 1926 when, along with Mark Anderson, we made a first report on the Loch Ossian plantations. Unfortunately the lodge was burned early in the war.

When I first visited Corrour Sir John had a famous forester named Simon Cameron. When we were just about to be introduced to Cameron for the first time I remember well Sir John saying 'if, by the way, Cameron makes slighting remarks about a Mr. Robertson you will realise that it is our colleague Robinson who is being criticised'. Many times after that when viewing the Corrour plantations with Cameron, and hearing of the early struggles to get trees to grow on Rannoch peat, Cameron would point admiringly to the tree growth all round the head of the loch and say 'hasn't Sir John a stout heart?' I often thought of that remark during the long period of Sir John's illness. There is no doubt about it Sir John had a stout heart until the end.

APPROACH AND PERSPECTIVE IN FOREST PATHOLOGY

By T. R. PEACE

SUMMARY

The author reviews briefly the lines along which forest pathology has developed from its emergence as a separate science up to the point now reached, where the influence of environment on the tree is too generally regarded as of greater importance than the actual pathogen attacking it. He would correct a major assumption, made by this school of thought, that the 'natural' forest necessarily provides the ideal environment, and that therefore any departure from nature, e.g. the use of pure stands or the planting of exotics is bound to encourage disease. He considers that forest diseases are mostly complexes, in each of which site and pathogen play very variable roles of differing importance. Any attempts at this stage to draw broad conclusions covering a large number of diseases are certain to lead to error. He suggests that, as producers of trees on a limited range of sites, and not as preservers of nature, we must avoid behaving as though 'unnatural' was the same thing as 'unhealthy'.

DURING the last 60 years forest pathology has advanced from its original position, as part of the rapidly developing subject of applied mycology, to its present status as an integral component of forest science. In making this advance it has moved on rather definite lines which will repay a brief review, before we pass on to consideration of a proper basis for forest pathology at the present time.

Even at the end of the last century, when Hartig published his *Text Book of the Diseases of Trees* (9, 1894), it was recognized that fungi and bacteria were not the only causes of tree disease; indeed, two sections of his book were devoted to diseases due to soil and atmospheric influences. In addition Hartig was well aware of the influence of environment on the diseases affecting trees; to quote Marshall Ward's preface to the English edition: 'I would especially emphasise this, that his researches are so thoroughly elucidative of pathological phenomena, in that he studies not only the nature of the structural lesions and of the physiological disturbances consequent on these, but also the factors of the environment which throw light on the question.'

Thus, from the first severance of forest pathology as a science in its own right, the importance of environment, both as a cause of disease without living aid and as an influence on diseases caused by pathogens, was recognized. Certain peculiarities of forestry, as compared with agriculture and horticulture, have made further development on these lines more or less inevitable. Even in countries where most of the forests are still natural, agriculture has superseded forestry on the more favourable sites for plant growth. In countries like Great Britain, where virtually all the natural forest has been destroyed by man, re-afforestation is almost entirely limited to those sites which are unsuitable, or at the best marginal, for agriculture. Thus, by the very nature of the soils and climates to which it has been driven, forestry is likely to be more influenced by site factors than its sister sciences.

In the forest we are dealing with a crop of long duration, so that the influence of environment on any one rotation of trees is prolonged. Thus the trees are often subjected to the whole range of climatic variation possible for the site. On the

other hand an arable or horticultural crop can be changed from year to year. Even with continued use of the same crop, failures in unfavourable years may well be offset by successes in favourable ones. In the case of forestry the comparatively low value per acre per annum of the growing trees limits expenditure on site amelioration, even if, with such a long period of continued growth in prospect, effective permanent amelioration were possible. In practice work on these lines has been limited largely to efforts, mainly by cultivation, to hasten the establishment of tree crops on initially difficult sites. Within its limits this work has been very successful and has led to a code of practice for many difficult site types. Agriculture, on the other hand, is often based on the progressive artificial improvement of the sites used. Thus inevitably the forester must be impressed with the irremovable influence of environment on his operations and particularly on the health of his trees.

By gradual development, therefore, from its original mycological background, forest pathology has reached its present stage, where the state of the host tree is considered before the pathogen attacking it, and where consideration of the influence of the environment on the tree and incidentally on the fungi or bacteria affecting it, has become the accepted method of approach.

In its development this conception of forest pathology has tended to become linked to certain more general forest theories leading in the same naturalistic direction. In the main these are all based on the idea that the 'natural' forest is the ideal environment. Such naturalistic theories include the ideas that, since pure stands are unnatural, they are, therefore, undesirable, and that the establishment of exotics in climates different from their own is unlikely to be successful; but the idea that concerns us most is that any departure from nature is bound to encourage the development of disease in the tree. It is no purpose of this paper to try to disprove theories, such as the above, which have an essential element of truth, but only to indicate their limitations, especially regarding their application to tree disease.

If we accept these ideas uncritically we can paint a very gloomy picture of the future of forestry in western Europe and particularly in Great Britain. Boyce (3, 1954) has ably summarized many instances of disease and failure in pure plantations and in stands of exotic trees. Day (6, 8, 1950 and 1955) has repeatedly stressed the amount of damage which trees suffer from the more extreme influences of their environment. It is all too easy to use this information for a series of unjustifiable assumptions, which lead to a belief that any pure or exotic stand on many of our forest sites is doomed to failure. This belief is not based on a proper investigation of the individual plantation, the site, and the disease influences present or potential, but on vague generalizations about disturbances of the biological balance, silviculture unnatural to the site, or ecological inadequacies bound to lead to disease.

It may help to put matters in proper perspective if we review these rather sweeping generalizations separately, briefly considering some of the diseases affected by them. Before doing so we must consider what we really mean by health and disease in a tree.

HEALTH AND DISEASE IN TREES

Normal health, both of the individual tree and of the forest, has been discussed by Day (6, 1950). Obviously there is an optimum level of health, but, as Day admits, this need not be reached, provided health is good enough to enable the tree to achieve the age or size required by managerial considerations. Although it is possible to define a healthy tree in very general terms, our real knowledge of what is implied by this expression is lamentably vague. We still do not know exactly how a tree functions or how much of its botanical structure is really required for efficient healthy growth. We are still more uninformed when we come to consider the effect of environment on the structure and functioning of the tree.

It is easy, but not necessarily correct, to assume that the loss of living organs by a tree, for example roots, must be a sign of present or impending ill health. For instance, Day (7, 1953) uses the word 'disease' to describe any damage to the structure of the tree, so that the dieback of the lesser roots, brought about by variations in the air and water content of the soil, is regarded under this heading. In all trees there is a certain amount of root death and regeneration of the fine roots, somewhat analogous to the shedding and regeneration of foliage, and it is, therefore, hardly logical to refer to rather more extensive dieback and regeneration of roots as disease, unless it results in permanent damage to the tree. It is admittedly difficult to define disease on any basis, but it seems most practical to refer to a tree as diseased when the amount of injury which it is suffering is such as to cause serious doubts about its future growth. This, of course, assumes that one is in possession of full information about the condition of the roots, as well as the portions above ground.

By our earlier definition, provided the tree will reach the age and size demanded by our managerial intentions, it is still in normal health. When of course it can be proved that present injury, not leading to immediate effects on the 'normal' health of the tree, will nevertheless result in a fall from that standard in the future, we are presented with a different picture. We can very seldom prophesy the future of a tree with reasonable certainty, because only a very limited number of long-term studies of tree disease have been made, and still fewer of tree health.

THE USE OF PURE STANDS

The reasons for the comparatively frequent use of monoculture in British forestry are outside the scope of this discussion. Suffice it to say that most of the plantations already established are in pure blocks, sometimes of considerable size, and that a change over to mixed planting would entail not only a major alteration in silvicultural policy, but also very largely a voyage into uncharted seas. By now we understand very well many of the difficulties, some of them pathological, associated with pure plantations; we know little as yet about those we would find with mixtures because so little mixed planting has been done. Unless we are to assume that mixed stands being more 'natural' than pure ones would therefore have no problems, we must admit that large-scale research on the establishment and maintenance of mixed crops, and from our point of view particularly on their

health, is long overdue. To attempt a major change without this preliminary research would be obviously undesirable.

Condemnation of monoculture is so general that it is scarcely necessary to quote references, but the objections have been ably summarized by an American committee on silviculture (2, 1939) and later by Boyce (3, 1954). It must be admitted that a pure stand is ideal for a pathogen to build up to epidemic proportions, since infection can pass directly from tree to tree. But it must be remembered that this will apply also to a mixed plantation, if the pathogen is one affecting all the species planted.

It has often been suggested, perhaps correctly, that larch canker is more severe in pure stands, but this information is derived for the most part from stands, the full history and particularly the seed origin of which are not known. It is now well established that larch of High Alpine origin is much more susceptible to canker than Scottish or Lowland origins. Many of the healthy larch in mixed stands are undoubtedly of Scottish or Lowland provenance. The High Alpine larches that were planted mixed, having been weakened by canker in their youth, may have been suppressed by other species in the mixture and either killed or removed, so that lacking records, the plantation no longer appears as a larch mixture.

Day (8, 1955) refers to attacks by *Armillaria mellea*, when conifers were planted on the site of old broadleaved woodlands, as an example of the effects of monoculture; but this must surely be regarded as a question purely of availability of infection centres in a planting of a susceptible species. Admittedly, if one constituent of a mixture had been more resistant, the damage would have been less. But the lowest level of attack would have been in a pure stand of the more resistant species. The fault here lies not in the failure to plant a mixture, but in the wrong choice of species. In any case damage by *Armillaria*, apart from plantings where each tree has an individual value, such as arboreta or seed orchards, seldom reaches a seriously damaging level. Spaulding is quoted (2, 1939) as saying: 'There are areas where *Nectria* (canker) seriously damages one species. If the stand is heavily of this species, the stand is ruined.' It is curious how seldom this argument is carried to its logical conclusion, namely that, if the stand is purely of a resistant species, there is no damage at all.

Inevitably the attack of a pathogen on a mixed stand, where one species is resistant, will appear less serious than in a pure stand of the susceptible species, merely because in the latter case a higher proportion of the total crop is affected. The mixed plantation is certainly now the 'better' stand of the two, but the actual damage to the susceptible species may well be the same in both.

It should also be remembered that sometimes in a mixture both species may be attacked, where only one is susceptible when grown pure. An example of this is to be found with *Fomes annosus* acting as a killing agent. Hardwoods are normally quite resistant to this fungus but when they are mixed with conifers fairly extensive killing has been observed on a number of occasions. In this case the build up of infection on the susceptible species is such that even the resistant one succumbs.

The behaviour of *Mycosphaerella laricina* on larch on the Continent also illus-

trates the complex effect of mixtures. In this needle disease reinfection normally takes place in the spring from fallen larch needles on the forest floor. If the larch is in mixture with spruce, some of the larch needles remain hanging on the lower twigs of the spruce throughout the winter, so that when the spores are produced in the spring they are nearer to the live crown of the larch than they would have been on the ground, and more severe infection results. On the other hand, when the larch are mixed with beech, the leaves of the latter cover the larch needles on the ground and prevent reinfection in the spring, thus greatly lessening the attack.

Boyce (3, 1954) goes so far as to say that the chances are strongly against the long-term success of pure stands, unless the species concerned forms such stands in its native habitat. It is this whole-hearted acceptance of a partial truth as a principle, which is the main purpose of this paper to discourage. A species growing naturally in pure stands may do so solely because it lacks efficient competitors in the places which it has so far successfully colonized. A species growing in mixed stands naturally may do so only because successful competitors are present. In any case the occurrence of pure stands in nature should have made it quite clear that such conditions are not necessarily 'unnatural'. It is unscientific to take these ecological occurrences, each of which, for a different species in a different place, may be due to a different set of controlling factors, and simplify them into a general rule for the practice of the highly artificial science of commercial forestry. Probably the greatest single factor leading to success in man's efforts to cultivate plants for his own use has been the removal of competitors; in very few cases is the plant allowed to continue in its natural ecological environment.

The author has no desire to deny that, in general, the disease potential of a pure stand is higher than that of a mixed one containing the same species. Though it may be desirable to remember that the most devastating tree disease so far encountered, Chestnut Blight (*Endothia parasitica*) destroyed chestnut in America mainly in mixed stands. It can be said that almost all agricultural crops are more liable to disease than their wild counterparts, nevertheless, the yield of usable material is invariably higher under managed cultivation. It is often suggested that this is due to the use of modern chemical disease-control methods, most of which are not applicable in forestry outside the nursery. But surely it is unnecessary to resign ourselves to the belief that we cannot elaborate methods of control lying between these inapplicable chemical methods on the one hand, and a slavish faith in the mixed 'natural' forest on the other. In any case there is little evidence in Great Britain that pure planting has, as yet, led to any major disasters. Nor, in the author's opinion, are any such disasters immediately imminent.

THE USE OF EXOTICS

Since we have only one native conifer of economic importance, it is disheartening to read in Boyce (3, 1954): 'Exotics are not all foredoomed to failure, but for every exotic the chance of failure is much greater than the chance of success.' It is undoubtedly true that there have been many cases of failure of exotics, either generally or on certain sites. The behaviour of Corsican pine at higher elevations in Great Britain, or the destruction of High Alpine larch by larch canker are cases

in point. It is in fact dangerously easy to quote instances of trees, reasonably healthy in their native lands, which are attacked by diseases when planted in a new country. These diseases may be due to non-living agencies to which the trees are not subject at home, to pathogens native to the trees and imported with them, but attacking them more virulently in their new environment, or to pathogens already existing in their new station, to which they are found to be susceptible.

But to accept the failure of exotics as a general principle is quite unjustified defeatism. In many of the examples that come to mind, consideration will reveal that the disease in question is not really a limiting factor on the cultivation of the exotic species; even if the tree is thereby less successful than it would have been if unattacked, the result is not failure.

Here again the principle of the natural habitat has been advanced. We are supposed to be taking the tree out of its proper growing conditions. This would assume that all species have had equal opportunities to colonize all parts of the globe, without interference from man, animals, or other plants. Palpably this is not the case; the occurrence of a species in a certain area may indicate nothing more than its ability to survive under the climatic, pedological and sociological conditions there existing. There is no reason at all to assume that it is experiencing there the conditions conducive to its best development. There will certainly be many places outside its natural range where the species will not thrive, and its planting there, if attempted, will produce another 'exotic' failure. But only by trial and error, or by ecological investigations of a complexity not yet attempted, can we find out what are the possible, and what are the best conditions for a particular tree species.

THE CONCEPT OF THE NATURAL FOREST

Both theories that have so far been considered, the supposed danger of pure stands and the risk inherent in the use of exotics, have been based partially on the concept of the 'natural' forest. The natural forest is normally mixed, therefore we ought to grow trees in mixture; the natural forest inevitably consists of native trees, therefore we ought to eschew exotics. The purpose of this paper so far has been to try and show that, while there is considerable evidence in favour of both these theories, it is not sufficient to justify an upheaval in British forest practice. It is also contended that the support given to these theories by appeals to the concept of the 'natural' forest is partially false, and almost wholly dangerous.

Without referring here to the very considerable continental literature on the subject, it is sufficient to say that the case for the 'natural' approach has been investigated and generally approved by an American committee on silviculture (2, 1939), while more recently it has been put briefly and readably in an article by Anderson (1, 1956). In his paper Anderson makes a strong plea for more and better ecological research, especially on forest soils, a matter on which all thinking foresters will give him support; but to imply, as he does, that this research must of necessity take the natural forest as its starting-point, is to put a quite unnecessary curb on our freedom of movement. It may well be that we shall find from this research, that it is desirable for the health of our tree crops to try and main-

tain or develop some factors of environment that are typical of the so-called natural forest; but if this is so, it should be because those factors are required for the successful growth of trees, not because they are 'natural'.

As practical foresters we are concerned with growing utilizable trees on the soils and in the climates at our disposal. To do so successfully those trees must attain a reasonable growth-rate, a certain level of health, and at least a utilizable age. We must endeavour at the end of the rotation to leave a soil on which further crops, at any rate not of lower value, can be raised. It is curiously defeatist to assume that we can only do this by a slavish adherence to nature.

For instance it has been widely suggested on the Continent that the only means of preventing attack by *F. annosus* is by the planting of mixed stands. The evidence in favour of this idea is seldom critical, and may have led to the neglect of more immediate remedies, such as the stump treatment suggested by Rishbeth (10, 1948), as a means of preventing the entry of the fungus into uninfected stands. Here of course we have no parallel in nature. Nature does not suddenly form plantations on large areas of *Fomes free* soil, nor does she thin her forests by the sudden cutting of healthy trees. No matter how 'natural' our forest, if we are to utilize the timber we shall produce 'unnatural' stump surfaces, suitable for infection by pathogens and their transmission to the remainder of the standing or to the succeeding crop.

It is certainly time for us to recognize that forestry, as we must practice it, is in fact tree farming. This statement is not intended to imply that the techniques need in any way be the same as those used in agriculture. For instance in the pathological field we can only use sprays, which are the basis of agricultural disease control, in our nurseries. For disease control in the forest we have to elaborate our own techniques. But surely forestry, like agriculture, should advance by the use of techniques that are based on research and on accumulated knowledge of artificial tree crops, to a stage where the trees we grow and the crops they produce are superior to those occurring in native stands.

Admittedly forestry in many countries is largely based on the use of existing natural forest, in the same way that agriculture in some places is based on the use of existing herbage. But there also we should keep the idea of improvement beyond the natural level always before us.

THE ENVIRONMENT AS A CAUSE OF DISEASE

Undoubtedly for every tree there is an ideal environment, though as has already been pointed out, there is no reason to assume that this ideal necessarily lies within the natural range. In forestry, however, we can improve the sites which we must use, only to a very limited extent, and our consideration is, therefore, not with the ideal but with the possible environment. Inevitably this means that trees will often be planted in places where one or more of the site factors are limiting to healthy growth, and that disease will sometimes ensue.

Day (7, 8, 1953, 1955) has on a number of occasions applied the term 'disease' to root growth restricted by soil conditions. Such restriction is certainly a very common phenomenon, undoubtedly sometimes associated, as Day has stated,

with decline of growth-rate, drought symptoms in the crown and stem, windfall, and other sources of loss. But a general survey of tree-rooting conditions would undoubtedly disclose that shallow rooting was far commoner than the troubles to which it sometimes leads. Every forester knows of trees which have reached a very large size on extremely shallow soils. Here again a fact of considerable pathological importance has been enlarged into an untenable general principle.

There are other environmental influences, such as frost, which on occasion can temporarily or permanently restrict tree growth. Exposure to wind-blast appears to be the main factor limiting the elevations at which we can plant trees. Such factors vary enormously from place to place and from time to time. Some, for example frost, alter vastly as the growth of the forest progresses. For none of them can we lay down rules of general application concerning their direct or indirect effects. In each case they must be studied in relation to the particular site with which we are concerned and the problems of that site.

THE EFFECT OF ENVIRONMENT ON FUNGAL AND BACTERIAL DISEASES

Preoccupation with the effects of environment on the tree, enforced by the supposed absence of disease in native stands, has led to an unjustified devaluation of the importance of fungi and bacteria *per se* in forest pathology. We are apt to forget that fungi and bacteria can and do attack healthy trees. Practically all diseases require certain climatic conditions for infection, and subsequent development. For instance, Elm Disease, *Ceratostomella ulmi*, attacks more severely in a hot summer. But in any case, many diseases are perfectly capable of attacking fully vigorous trees. Elm Disease itself, bacterial canker of poplar, *Rhabdocline pseudotsugae* on Douglas fir, *Keithia thujina* on *Thuja*, all the rust fungi and many others, are in this category.

Some fungi do, and others appear to develop more freely on trees which are already weakened. It is necessary to remember that recovery from disease is largely a matter of vigour, so that weakened trees will respond more feebly and therefore, by lack of recovery, appear to be the more severely attacked. The environmental factor which weakened the tree has certainly contributed to its final condition, but it cannot strictly be said to have favoured the fungus. For instance, *Meria laricis* will attack a vigorous larch with the same freedom as a weak one, but, owing to the poor recovery of the latter, it will appear to be the worse attacked. A clear distinction between this sort of occurrence and a real effect on degree of attack would often save confusion.

Nevertheless it is true that there are many fungi whose attack is influenced indirectly by the effect of environmental conditions on the tree. *Brunchorstia destruens*, as it affects Corsican pine, normally, though not invariably, attacks after the trees have been weakened by unsuitable site conditions. *Dasyscypha* (*Trichoscyphella*) *willkommii*, the fungus associated with larch canker, though now shown to be capable of causing cankers by itself, is undoubtedly greatly assisted by frost. Attack by *F. annosus* is greatly influenced by site, and some of this influence is probably operative through the health of the tree; though here again we find attacks developing in some of our best stands. But in the case of *Fomes* it is neces-

sary to sound a note of caution. Rishbeth (11, 1950) has found that site differences affecting *Fomes* attack in East Anglia are associated with the presence of a competing saprophyte. Disease-affecting site differences such as this, which have no bearing on the health of the tree, except through their effect on the fungus, may well operate in other cases. Day (4, 1948) has postulated that *Fomes* is a fungus which may act as a virulent parasite, when adverse conditions in the soil induce susceptibility in the tree. This may well be the case, at any rate on some sites, but it would be very rash on our present knowledge to assume that *Fomes* attack in the future can be avoided by silvicultural measures designed to produce 'healthy' trees; even if we knew what those methods were and how to apply them to our sites.

It has also been suggested by Day (5, 1948) that frost injury is the basis of bacterial canker of poplar. This theory is based on the occurrence of abnormal tissue suggestive of frost in a number of cankers examined. It is true that poplars can be injured by frost, and that typical rings of distorted cells, which are an almost certain sign of frost injury, do occur in them. But it is also known that severe distortion of wood and bark cells can be caused by fungal or bacterial invasion, and this assuredly accounts for much of the abnormal tissue associated with poplar cankers. Observation of the numerous frost-free sites where bacterial canker of poplar occurs and its failure to vary in intensity of attack according to the degree of occurrence of damaging frosts, must surely disprove this theory, and leave bacterial canker, to a great extent, a disease in its own right. The same misinterpretation of deranged tissue, since abnormalities caused by the fungus *Dasyscypha* have been attributed to frost, has led to an exaggeration of the role, admittedly important, that frost plays in larch canker.

It would be possible to quote many other cases where the role of environment in fungal or bacterial diseases has been misinterpreted, and many more where our knowledge is insufficient for any expression of opinion. It is desirable to realize that most tree diseases are matters of considerable complexity. The influence of the environment may be exerted either through the tree or on the pathogen in the most indirect and unexpected ways. Any attempt to simplify these relationships by the enunciation of a general principle, at any rate in the present state of our knowledge, is more damaging than helpful.

CONCLUSION

It may seem that in attacking so many widely held concepts, a disservice is being done to the establishment of order in the pathological branch of forest science. It is the author's view, however, that broad assumptions at the present stage can lead only to false simplifications. We know regrettably little about health and disease in trees. We should therefore beware of cramping further advances by an attempt to base them on partially false premisses. It is necessary here to lay great stress on the word 'partially', for in all the concepts discussed above there is an element of truth.

We must remember that in forest pathology, as in other branches of forest science, we are producers of trees, not preservers of nature; our aim is to produce the best we can with the sites at our disposal, and our methods of research and

subsequent technical advances must be based on the assumption that the complex relationships of site, climate, trees, and pathogens, with which we have to deal, are as yet too unknown to be explained by broad generalizations. Above all we must avoid behaving as if the word 'unnatural' was synonymous with the word 'unhealthy'.

Thanks are due to J. S. Murray, H. G. M. Dowden, and J. D. Low for their helpful assistance and criticism.

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BRITISH ASSOCIATION, DUBLIN, 1957

The British Association for the Advancement of Science will meet in Dublin from 4th to 11th September. The Forestry Sub-section will meet under the chairmanship of Mr. T. McEvoy, Department of Lands, Dublin. His address will be 'Forestry in Ireland'. There will be a joint session with the Botany Section on the Ecology of Peat and Peat Afforestation (papers by K. F. Parkin and R. E. Parker). There will be sessions on Forest Management, Silviculture of Underdeveloped Areas, Forest Economics, Forest Roads, and on Utilization. Speakers include F. C. Hummel, W. E. Hiley, and E. R. Huggard. Excursions will be made to forests round Dublin. Further particulars may be obtained from Mr. T. H. Owen, Department of Forestry, University College of North Wales, Bangor.

THETFORD CHASE, SWAFFHAM, AND KING'S FORESTS. FURTHER NOTES

By G. W. BACKHOUSE

(*Forestry Commission*)

SUMMARY

Continues the history of the development of these East Anglian pine forests from the point reached by James Macdonald in 1938 (*Forestry*, xiii. 1–18). After describing the effect of the war on the area, it deals shortly with climate, present planting methods, thinning and production, utilization, protection, and organization.

INTRODUCTION

IT is now 18 years since the article by Macdonald (5) appeared in this journal and the impending visit of the Society to the areas makes it opportune to bring the story up to date.

Since 1938 the momentous happenings in the world have had a considerable effect on the locality in which these forests are situated. Large areas of what was then heathland are now in agricultural production and the remainder with small exceptions are now firmly held by the Service Departments. It is therefore not surprising that further acquisitions for forestry purposes have been on a very limited scale. The total area of each of the forests and the actual area under plantations are given in Table I. These figures are not strictly comparable with those in Tables I and II of Macdonald's article as certain parts of what were then included in Swaffham Forest have been transferred to the Thetford Chase.

TABLE I. *Area of land*

Forest	*Total area acres*	*Area under plantation acres*
Thetford . .	49,747	35,677
King's . . .	5,954	5,198
Swaffham . .	3,810	3,286
Total . . .	59,511	44,161

The effects of the war were far reaching within the plantations themselves. Most of the acquired plantations were felled and the land has now been replanted. Few of the old hedgerows remain but it is hoped to preserve at least one typical example. Thinning had already begun in 1938 and although a considerable area was thinned during the war, arrears of thinning accumulated steadily. A further important result was the neglect of maintenance of many of the younger plantations and it was most unfortunate that large areas of mixed broadleaved and coni-

ferous plantations reached a stage of development when essential treatment should have been given at a period when no labour was available.

Much of the forest was used in one form or another for military purposes. Extensive areas including the whole of the King's Forest were taken over completely, fences were removed, rabbits took over, tanks and other military vehicles overran the plantations, and the final result was appalling, necessary though it may have been.

CLIMATE

In the years 1938 to 1956 the climate has followed the pattern indicated by Macdonald. There have been wet years (1950 and 1954) and very dry ones (1947 in particular), and there have been exceptional frosts in the growing season resulting in very serious damage to plantations. That of June 29/30 1954 severely damaged young Corsican pine (*Pinus nigra* var. *calabrica*) and even Scots pine (*P. sylvestris* L.). The minimum grass temperature on this date fell to 22° F.

Table II shows the monthly rainfall from 1939 to 1954 and Table III the number of nights with ground frost.

THE NEW PLANTATIONS

The technique of preparation of the ground for planting has undergone no radical change. Wherever possible shallow single furrow ploughing has been carried out using a plough with a double breast, the result of which is to produce a wider furrow with an upturned ridge on both sides resulting in more effective suppression of vegetation. Great emphasis has also been placed on subsoiling and it is now standard practice for the plough to be fitted with a suitable subsoiling tine.

The choice of species has changed slightly in the last 10 to 15 years and the replacement of Scots pine by Corsican pine in planting work is now almost complete. Additional large areas of mixed pine and beech (*Fagus sylvatica*) have been planted in King's Forest and small areas of oak (*Quercus* spp.) in the Thetford Chase.

The belts of broadleaved trees planted along roadsides for amenity and fire protection have had varying success. Many are now almost pure broadleaved following removal of the pine nurses, but in considerable areas the broadleaved species succumbed to frost or were badly suppressed by the pine nurses during the war years. An effort has, and is, being made to rescue the relics and get at least mixed belts. The more recently planted amenity belts have been established more successfully than was the case in the past because of improved technique.

A plan has been formulated for dividing up the whole of the Thetford Chase into blocks of 200 acres or so using broadleaved belts one chain wide. It is hoped that these will ultimately have permanent value against crown fires and as shelter when establishing subsequent crops.

Of the species originally planted there is no doubt that Scots pine and Corsican pine have been by far the most successful. Almost everywhere they have produced most satisfactory stands. Corsican pine has, as would be expected, proved to be the

TABLE II. *Monthly rainfall at Thetford (Lynford) in inches*

Month	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*
Jan.	4·54	1·86	2·06	3·29	4·36	1·90	2·40	1·47	1·71	4·24	0·94	0·62	2·94	2·36	0·97	1·74	1·87
Feb.	0·92	1·79	2·37	1·11	0·80	1·25	1·82	1·62	1·11	0·74	0·99	3·57	2·75	0·85	1·36	2·12	2·95
Mar.	2·10	2·66	3·69	1·88	0·56	0·31	1·65	1·20	4·54	0·59	0·87	0·43	3·61	2·84	0·56	2·59	1·72
Apr.	2·03	1·35	1·3	0·90	0·92	1·53	1·18	1·01	1·40	1·64	1·88	2·33	3·24	1·40	2·54	0·30	0·71
May	1·05	1·13	1·79	1·77	1·55	1·35	2·80	1·25	0·63	4·30	2·05	2·07	1·69	1·51	1·93	2·36	2·45
June	1·58	0·69	1·16	0·92	3·08	1·64	1·69	2·79	2·92	2·17	0·76	2·51	1·25	1·12	3·15	2·30	1·95
July	2·31	2·26	1·91	3·52	1·32	3·45	1·02	6·95	1·13	1·71	3·25	6·77	1·06	1·16	2·84	2·74	0·11
Aug.	2·56	0·31	4·09	1·52	1·80	1·40	3·06	3·19	0·10	2·74	1·35	3·11	2·95	3·23	2·21	5·05	1·05
Sept.	2·15	0·93	0·44	2·04	1·80	3·18	2·97	2·81	0·98	1·57	1·07	2·64	2·46	2·36	1·21	1·82	2·11
Oct.	4·32	1·72	2·06	3·43	1·74	3·14	2·67	1·47	0·31	2·46	3·74	1·05	0·77	2·71	2·17	2·65	2·91
Nov.	3·76	6·11	2·08	3·0	1·72	3·15	0·86	3·67	1·46	0·91	2·27	4·65	2·77	3·98	1·33	4·83	1·15
Dec.	1·54	1·89	1·48	2·61	1·12	1·01	2·60	2·21	2·84	1·99	1·86	2·10	1·58	2·18	1·03	1·93	1·54
	28·86	22·7	24·43	25·99	20·77	23·31	24·72	29·64	19·13	25·06	21·03	31·85	27·07	25·70	21·30	30·43	20·52

TABLE III. *Number of nights with ground frost, Thetford*

Month	*1939*	*1940*	*1941*	*1942*	*1943*	*1944*	*1945*	*1946*	*1947*	*1948*	*1949*	*1950*	*1951*	*1952*	*1953*	*1954*	*1955*
Apr.	13	11	17	14	12	16	11	19	19	25	25	18	21	14	22	..	15
May	10	12	13	13	7	14	5	14	5	23	16	17	3	8	12	13	18
June	5	3	1	6	..	5	..	..	6	16	7	..	5	2	2	2	5
July	2	1	..	..	..	..	3	..	1	6	12	..	1	3	..	3	..
Aug.	..	3	..	..	2	..	..	..	6	..	15	..	..	1	2	..	..
Sept.	..	..	..	..	..	..	..	1	14	2	6	..	3	19	8	4	6

Note: Figures are not strictly comparable with those given by Macdonald as the site of the Meteorological Station was changed.

faster growing and the more productive of the pines. The very extensive areas of this species planted in 1925 and 1926 are a joy to see. Scots pine has not grown well on the poorest deep sands and there are other poor areas caused by the use of bad plants and a variety of other factors.

Except in the species trials *P. contorta* has nowhere proved satisfactory and it is fortunate that it was used on such a limited scale. Certainly this species appears to have suffered worst from the pine-shoot moth (*Evetria buoliana*) (1).

Of the extensive areas originally planted with European larch (*Larix decidua*) few now remain as pure larch and some of these are very poor. Frost and die-back have been very severe but on the more fertile sites reasonably free from frost growth has been very satisfactory.

Japanese larch (*L. leptolepis*) was used on a very limited scale; generally it has been a complete failure and there is little doubt that the rainfall is too low for this species.

Little use of Douglas fir (*Pseudotsuga taxifolia*) has been made in recent years and generally it has been restricted to frost free areas and preferably under shelter. The older areas of Douglas fir described by Macdonald are now satisfactory but growth and production is only similar to that of Corsican pine. There is little doubt that it is best grown in mixture with one of the pines to promote stability on the loose sands.

The areas originally sown with Maritime pine (*Pinus pinaster*) and heavily beaten up have been converted during thinnings to pure Scots pine. Maritime pine is not a suitable tree in this forest.

Sitka spruce (*Picea sitchensis*) was used on a very limited scale on carr land. It has suffered badly from frost and attacks of *Myzaphis abietinae* but still grows reasonably well. Norway spruce (*Picea abies*) was restricted to one plantation in Brandon Park: a low-lying area with comparatively high water table carrying a calluna–molinia vegetation. Growth has been very slow and it is obviously an unsuitable species.

Of the other conifers Western hemlock (*Tsuga heterophylla*), Lawson's cypress (*Chamaecyparis lawsoniana*), Western red cedar (*Thuya plicata*), Grand silver fir (*Abies grandis*) have all been established without difficulty under shelter on suitable sites and there is no reason why these and other species should not be used on a moderate scale in subsequent rotations.

The extensive areas planted with beech with conifer nurses have had a chequered career. However, considerable areas are now well on their way to producing a satisfactory crop of beech. It is now generally accepted that beech is better not planted along with the nurse crop but introduced after the second or third thinning.

The oak plantations have been less of a trial than the beech ones and most are now growing normally and are approaching the time when a first thinning will be required. It is a matter of regret that many of the pine–oak and pine–beech areas planted in the early thirties, planted as they were in very intimate mixture, suffered from neglect in the war years.

Poplar (*Populus* spp.) was used extensively on the wet land along the rivers but

many sites proved too wet even for this species. Bacterial canker has taken its toll in many other sites and really satisfactory plantations are not extensive though post-war plantings promise well.

Of the other broadleaved species but little use has been made. Cherry (*Prunus* spp.), Norway maple (*Acer platanoides*), Lime (*Tilia* spp.), and Red Oak (*Q. borealis*) appear to promise well though only the former is really frost hardy. It is worth noting that on the Croxton beat there is a very attractive area of naturally regenerated lime resulting from a war-time felling. A mixed broadleaved amenity belt in King's Forest shows excellent growth of *Nothofagus obliqua*.

THINNING AND PRODUCTION

All plantations of conifers are fully brashed when the branches to a height of 8 feet or more are completely dead; the operation being done by bill-hooks.

Prethinning or earlier 'wolfing' described by Macdonald is not now carried out as experience has shown that it is only in exceptionally poor plantations that badly shaped trees cannot be completely removed in the first two thinnings.

During the war years the practice of 'line-thinning' in the pine plantations grew up. This technique has been described by Flentje and Gough (3). The principle is to remove complete rows of trees instead of selecting individuals. At first half the crop was cut by removing either two rows out of four or three out of six but this was found to be too drastic except in the fully stocked stands of uniform growth. Other variants were two rows removed out of six, eight, or twelve and one row out of three or four. This method of thinning has two main disadvantages: (i) it removes trees that ought to remain, (ii) it leaves trees that ought to be removed.

However as a war-time expedient it had certain advantages: (i) no selective marking required, (ii) a higher proportion of the bigger trees are cut and hence provide a larger amount of pit-prop material than would a selective thinning, (iii) felling and extraction are facilitated.

After the war the whole policy of line-thinning came under review. Adequate labour and skilled supervision were available to enable a return to more orthodox methods and this was decided upon. However it was appreciated that line-thinning had one great advantage which ought to be retained—that of access for removal of poles. Hence it was then laid down that at the time of first thinning two rows in every thirty rows should be completely removed. This has now been standard treatment for 8 years or so. The racks so cut provide ready access to all parts of the forest by lorry and tractor for extraction purposes and by fire tender for fire fighting.

Between the racks normal selective thinning takes place. The grade of thinning adopted for the pines is what is known in the Forestry Commission as the 'Silvicultural Grade'. It corresponds fairly closely to the 'C' grade but rather more dominants are removed than in the strict application of this grade; this gives the remaining dominants room to develop. It is a compromise grade which aims at development of saw logs at an early age but without completely sacrificing quality. An explanation of the abbreviations used for thinning grades, e.g. 'C'

above, and 'HC', 'A', and 'D++' further on in this paper, will be found in *British Commonwealth Forest Terminology* (2), and in Hummel's 'Thinning Study in Young Pine' (4).

The first thinning of the pines normally takes place when the average height of the dominants is 25–30 feet. This is normally achieved in Scots pine at an age of 20 to 22 years from planting and 18 to 20 for Corsican pine. As thinnings extended, the advantage of thinning in blocks was appreciated and gradually this was achieved. This concentrates marking, felling, and extraction, thereby enabling the work to be done more economically and systematically. The blocks vary somewhat in size and each beat may have several series of blocks.

Until 1955 the practice was to repeat thinnings in Scots pine at 5-year intervals and in Corsican pine at 4 but in that year the whole thinning policy was reviewed and it was decided that it would be preferable to use a 4-year cycle for both species. This enables the block system not only to be developed further but more important to extend the interval between the third and fourth thinnings to 8 years without upsetting the system. This change will take several years yet to become universal as a drastic change would have interfered with production. The 4, 4, 8, 8, &c., cycle for thinning in the pines is not rigidly applied, no plantation is thinned unless a worthwhile number of stems can be removed though this is exceptional nor does it debar a 4, 4, 4, 8 cycle in fast-growing Corsican pine.

Douglas fir is normally thinned on the same cycle as the pines and a similar grade is used but an effort is made to retain sub-dominants where possible. European larch is thinned to the HC grade where it occurs in pure stands.

The thinning of the mixed broadleaved conifer plantations is somewhat of a problem and has undergone changes. In the early years after the war the policy was to remove the conifer from the oak mixtures as quickly as possible preferably in two cuts at 2-year intervals but some were done in one cut. There is little doubt that this was too drastic and had an adverse effect on the growth of the oak. Present policy is to remove more gradually and to retain a moderate stocking of a conifer in the interests of production of coniferous sawtimber.

The policy with the mixed beech–conifer plantations was to remove the conifer as quickly as possible consistent with preserving the cover against frost. Again some cutting was too drastic and now the policy is to remove only sufficient of the conifer to relieve beech at a spacing of 30 feet. The object is to retain the conifer to an age of 80 years or so, a few longer if possible and finish up with an open final crop of beech, which should put on good increment and yet protect the soil by the sub-dominant beech.

Table IV shows the acreage thinned and felled since 1938. Most of the felling took place in acquired plantations as did all but the last 2 years of thinning in the King's Forest.

It was hoped to high prune all high quality stands particularly Corsican pine and 1,250 acres were covered by 1952 when it became necessary to apply the strictest economy. However, a new but limited start has now been made. High pruning is carried out on 150 to 250 trees per acre selected after the first thinning.

RATES OF GROWTH

A considerable number of sample plots have been laid down in the forests, covering most species planted in any quantity and grades from 'A' to 'D++' and 'LC'. These plots show that Corsican pine is generally quality class 1 to 2, Scots pine 1 to 2, European larch 2, Japanese larch 2 to 3, and Douglas fir 3.

PRODUCTION

In the early post-war years a very large number of $\frac{1}{10}$-acre plots was measured in areas marked for thinning and from the information obtained it was deduced that it was reasonable to remove in thinnings from the twelfth year onwards

TABLE IV. *Acreage felled and thinned*

	Thetford		*Swaffham*		*King's*	
Year	*Felled*	*Thinned*	*Felled*	*Thinned*	*Felled*	*Thinned*
1940	423	174	5	6	147	34
1941	222	108	..	..	193	34
1942	145	185	10	17	91	4
1943	147	242	17	314	108	..
1944	221	207	58	278	3	7
1945	66	786	22	403	17	..
1946	56	839	8	401	13	..
1947	14	2,547	84	466	..	83
1948	43	4,217	..	41	..	118
1949	102	5,842	20	504	..	80
1950	81	6,057	..	347	6	86
1951	312	5,329	9	397	76	27
1952	398	5,034	..	378	6	23
1953	57	4,700	..	250	32	122
1954	45	4,604	5	298	13	94
1955	48	4,924	6	378	6	142
1956	88	4,597	6	520	11	269
Totals	2,468	50,392	250	4,998	722	1,123

50 cu. ft. per acre per annum in the case of Corsican pine and 35 to 40 cu. ft. in Scots pine (volume to $1\frac{1}{2}$ inch diam.). This does not include volume removed in cutting racks and applies to a well-stocked plantation. These figures are a very useful check on actuals removed and have been used for forward forecasting.

Volumes up to 600 h.c.f. (o.b.) per acre have been obtained at a first thinning where stocking was abnormal due to natural regeneration and work was delayed, but the normal at a first thinning is between 350 and 450 h.c.f. (o.b.). At the second thinning this falls to an average of 175 to 200 h.c.f. per acre.

UTILIZATION

During the war a small conversion depot was set up on land adjoining Brandon railway station and when production increased after the war it was decided as a

matter of policy to concentrate conversion in this enlarged depot, now covering 21 acres. A similar depot was later set up at Swaffham.

Investigations have shown that conversion in a depot in forests such as these, where access is so easy, costs about the same as where done at stump or on ride. Administratively the advantage is all with depot working.

Thinning is done on piece-work and the volume is calculated by a system based on local volume tables. The poles are carried to the racks by the fellers—where they are graded by size and those destined for pitprops are peeled in the length. The larger poles are removed by tractor and when they exceed a specified size the butt is cut off and removed separately. Some 95 per cent. of the volume removed

TABLE V. *Yearly production from thinnings in h.c.f. (o.b.)*

	Thetford	*Swaffham*	*King's*
1948	1,184,000	*	*
1949	1,517,000	142,303	*
1950	1,695,000	114,040	*
1951	1,618,000	96,234	4,577
1952	1,909,103	80,058	5,270
1953	1,552,135	75,523	24,142
1954	1,426,413	89,272	15,748
1955	1,580,949	121,920	20,624
1956	1,411,658	160,790	83,574

* No figures available.

in thinnings is transported to the depots and here converted into the many products for which a ready sale is obtained.

Thirty-eight per cent. of the intake into the depot is converted into peeled pitprops of fifty different sizes. Approximately 47 per cent. of the volume is sold as pulpwood of three sizes and the remaining 15 per cent. comprises miscellaneous poles, fencing stakes, harvest poles, boxwood, and firewood. The small percentage of timber sold direct from the forest is almost entirely boxwood.

A small amount of thinnings in Swaffham Forest are sold standing but as a matter of policy the sale of standing thinnings in the Thetford Chase is not contemplated.

An open tank creosoting plant is maintained at Santon Downham which deals with 80,000 pine fencing stakes each year. The Conservancy requirements are met from this leaving a useful margin for sale.

GENERAL ORGANIZATION

The forests fall into three separate districts but all district officers are based on the administrative centre at Santon Downham. Liaison is of necessity very close. The Thetford Chase itself is divided into fourteen separate beats, the conversion depot is under the charge of a separate forester as are Swaffham and King's Forests.

At the administrative centre at Santon Downham are located the estate staff,

headed by a clerk of works, which attends to the care of the numerous properties and the mechanical workshop where the large pool of lorries, tractors, and a variety of other items of mechanical equipment are maintained. With very few exceptions all mechanical equipment used in these forests is owned by the Forestry Commission.

A seed-extraction plant and seed store are also sited at Santon Downham and each year some 3,500 bushels of cones are dealt with producing 2,250 lb. of clean seed.

NURSERIES

All the nurseries in existence in 1938 have been, or are in process of being, abandoned. A new wasteland nursery at Roudham and several small woodland nurseries on cleared areas within the forest have been opened up. The total area is 56 acres and as planting in the forests is now negligible the nurseries produce largely for export.

A poplar nursery is maintained at Harling and a smaller research one at Mundford, the latter being used entirely for testing new hybrids for resistance to bacterial canker.

ROADS

The forests are traversed by a number of public roads giving ready access to all but the largest blocks. Almost every ride throughout the three forests is usable by lorries and the greater proportion by careful car drivers. As already described lorries penetrate plantations via the racks and hence almost every part of the forests can be reached for extraction or fire-fighting purposes. The terrain and the nature of the soil are primarily responsible for this happy state of affairs but much has been done to improve access by the use of the patrol grader.

For more rapid movement and where traffic is very heavy something more is required and for these reasons 32 miles of metalled roads have been constructed in recent years.

FIRE PROTECTION

The protection of the forests from fire is a problem of the greatest importance. The extensive areas of coniferous plantations, mostly in the pole stage, combined with the low rainfall, sandy soil and 7 miles of main line railway combine to produce a serious hazard. In a dry year such as 1949 or 1955 danger of a high degree can be experienced continuously from mid-February until the end of September. The value of plantations at risk is very high and exceptional methods of protection are fully justified. Two factors assist greatly in dealing with the problem; firstly the existence of a very good network of public roads and secondly the nature of the terrain which enables motor vehicles to travel almost anywhere in the forest.

The protective system is based on early detection of outbreaks and rapid counter action. Detection is by means of fire towers of which there are five in the Thetford Chase and one each in Swaffham and the King's Forests. With these there is complete coverage of the forests and at least two cross bearings can be given for any

outbreak. The towers are all connected to the G.P.O. telephone system as is the central control point at the district office. This latter is manned by a district officer during periods of high risk and with him is a fire warden. These two are responsible for the day to day arrangements for manning the towers and for putting into effect the whole of the fire-fighting machinery should an outbreak occur. At the control centre are located three fire tenders, each four-wheel drive lorries, fitted with 400-gallon tanks, a motor pump and 200 feet or more of rubber hose mounted on live reels. There are single fire tenders in both Swaffham and King's Forests. All tenders carry additional equipment in the form of hand tools and manually operated pumps. The fire duty officer is equipped with a Land Rover

TABLE VI. *Acreage destroyed by fire*

	Forest				*Forest*		
Year	*Thetford*	*Swaffham*	*King's*	*Year*	*Thetford*	*Swaffham*	*King's*
1940	444	57	57	1949	..	..	..
1941	162	..	..	1950	..	..	..
1942	263	..	..	1951	..	..	..
1943	89	..	..	1952	2	..	2
1944	21	..	..	1953	3	1	..
1945	12	..	..	1954	19	..	..
1946	258	..	..	1955	7	..	..
1947	13	..	..	1956	3	..	..
1948	..	..	..				

which has its own water tank and a pump which can be operated from the engine while travelling. This organization is by no means independent; the local County Fire Services are equipped with tenders specially suited for forest fire-fighting and have given wonderful service for many years.

There are few natural sources of water within the forest and hence supplies for fire-fighting have to be provided. These take the form of 3,000–5,000-gallon tanks spaced at approximately one-mile intervals throughout the forests. Within the last 3 years the organization has been strengthened by short-wave radio equipment. This provides rapid communication between fire-fighters and the fire-control point and back to the base at the district office.

Table VI shows the area of plantation destroyed each year since 1938. The railway is responsible for a very large number of small outbreaks—in a bad season up to two thousand which are dealt with by a patrolman and are not recorded separately.

PROTECTION

(i) *Rabbits and hares.* Always two of the most serious enemies to the forester in Breckland, they multiplied rapidly during the war years when most of the forests were overrun by the military. It was impossible to maintain fences adequately and there was insufficient staff to keep the rabbits in control. Extensive areas of young plantations were completely destroyed.

The magnitude of the rabbit problem can be gauged from the fact that it took 5 years, seventeen warreners, and many miles of netting to clear the King's Forest alone, but 82,000 rabbits were taken in the process.

Myxomatosis killed all but a few rabbits in the infested areas surrounding the forests; unfortunately a few are coming back. As a matter of policy the external fences around all three forests will be maintained.

(ii) *Deer*. There is a small herd of fallow deer in the King's Forest but nowhere else. Roe deer have always been a nuisance at Thetford and drastic action had to be taken to reduce numbers in the nineteen-thirties. Populations were low towards the end of the war but when counter-measures were relaxed soon increased. The present state is that in the Thetford Chase there is estimated to be some 153 head of roe deer. The population in Swaffham and King's is small by comparison. Control is now effected by rifle shooting and high-stands to facilitate this are to be erected.

(iii) *Red Deer*. As the plantations have developed into a stage more attractive to red deer their numbers have increased. The originals would almost certainly be escapes from deer parks. The population is difficult to fix as they move about so much but herds of sixteen have been seen and the total is probably around thirty head.

(iv) *Squirrels*. The grey squirrel is not known in any of the forests. The red squirrel is common and at times action has to be taken to reduce the numbers in order to prevent damage to the pine. Damage has occurred in several places in the last 2 years, nowhere serious, but sufficient to act as a warning of what can occur if numbers get out of hand.

(v) *Insects*. Damage by the pine shoot moth is now insignificant. The pine sawfly *Lophyrus pini* is still present but has nowhere done serious damage. The pine weevil *Hylobius abietis* is a normal inhabitant of the forests and generally causes insignificant damage but has given trouble locally where old woods have been underplanted or burnt areas replanted too quickly. The pine shoot beetle *Myelophilus piniperda* again is present in small numbers almost everywhere, it breeds on trees killed by other factors and which it is impossible continually to clear up. It can increase to alarming proportions very quickly provided adequate breeding material is available and an example of this is as in 1947 when the spring gale brought down individual trees over the whole area. However this insect has proved easy to control by depriving it of breeding material and by constant trapping. The former necessitates rapid removal from the forest of all rough-barked thinnings or peeling them. A rigid rule is imposed that no such material may be left in the forest for more than three weeks—or it must be peeled and a further 3 weeks is allowed in the conversion depots. *Hylastes ater* has given slight trouble in young pine regeneration but again control is effected by the standard method of trapping. The pine looper, *Bupalus piniarius*, is present in all areas but careful pupal counts are made annually so that action can be taken before the population rises to the level of an epidemic.

(vi) *Fungi*. The only fungus which is currently causing serious damage is *F. annosus*. The status of this fungus has been investigated and described by

Rishbeth (6, 7, and 8) in *Forestry*, and a further paper by him will be found in this number.

EMPLOYMENT

The important differences from the position appertaining in 1938 are firstly the great increase in the number of men employed due to production work and secondly the steady employment provided. There is now no seasonal variation and hence a more stable labour force has been built up and the men have hence developed greater skill.

The maximum number of men employed was in 1948 to 1949 when arrears of thinning were being overtaken and large scale planting programmes done in the King's Forest; the numbers then were: King's 58, Swaffham 122, Thetford Chase 648. These were augmented by part-time labour in the form of students from the Lynford Foresters' Training School. Numbers of men employed at present are King's 28, Swaffham 25, Thetford Chase, 352, thus averaging one man per 131 acres planted at Swaffham and per 101 acres at Thetford. All figures are exclusive of supervisory staff.

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HONOUR

In Her Majesty's New Year Honours List. Sir Henry Beresford-Peirse Bt., Deputy Director-General, Forestry Commission, to be Companion of the Most Honourable Order of the Bath. Sir Henry is a fellow of the Society and a member of the Society's Council. A paper by him on the work of F. A. O. is printed in this number.

SOME FURTHER OBSERVATIONS ON *FOMES ANNOSUS* FR.

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SUMMARY

In a wide range of British forests *Fomes annosus* attacks originate from stump infection following thinning and under suitable conditions a relation can be found by sampling between the number of trees killed and the proportion of stumps earlier infected. In East Anglia very dry weather apparently favours stump infection, which otherwise often reaches a maximum in late winter. There is a general tendency for stump infection to increase. In Thetford Chase attacks on many acid soils have become stabilized, whereas those on some alkaline soils are still progressing. Recent estimates of economic loss through killing and butt-rot are compared. Experiments show that stump treatment gives excellent protection against killing, and the present large-scale creosoting of stumps in East Anglia is also effective. An outline is given of recent research on stump treatments.

INITIATION OF ATTACKS

IT is now clear that attacks by *F. annosus* Fr. usually originate from infected stumps, either of the current crop, produced by operations such as thinning, or of a previous crop. Whether the root infections eventually cause death, lead to butt-rot, or are halted before causing appreciable damage depends upon many interacting factors.

Killing of young pines (*Pinus sylvestris* L. and *P. nigra* var. *calabrica* Schneid.) on sites formerly bearing conifers is well known in East Anglia and probably occurs widely. Instances were seen in Scotland where the proportion of deaths, about 12 per cent., corresponded with that found on light, acid soils in the former area. Butt-rot has been widely reported in second-rotation conifer crops, and in 1955 instances of stain and usually of rot were seen in plantations aged 19–27 years in Wales and Scotland. The species affected and the approximate percentage incidence of attack, where estimated, were as follows: European larch (*Larix decidua* Mill.) 50, 50, 30; Japanese larch (*L. leptolepis* Gord.); Norway spruce (*Picea abies* Karst.); Sitka spruce (*P. sitchensis* Carr.); Western hemlock (*Tsuga heterophylla* Sarg.) 60; and Western red cedar (*Thuja plicata* D. Don) 60. Incidence of rot had sometimes increased sharply in the last few years, but rot was generally confined to the base of the stem in these comparatively young trees. In several instances initial infection was traced to contact between tree roots and old stump roots containing the parasite.

In first-rotation crops the part played by various operations in starting *F. annosus* attacks has become more apparent now that a considerable area of planted conifers has reached an age of 25–30 years. Operations may be listed in the following order of importance, at least as a source of loss by killing.

Thinning. In East Anglia, particularly on alkaline sites, severe damage has often

followed first thinning when carried out in plantations younger than about 16 years. Damage is less severe when first thinning is delayed longer, but may still be considerable even when this operation is performed in plantations 20–25 years old. The species most commonly affected are pines, but the less commonly planted European larch and Douglas fir (*Pseudotsuga taxifolia* Brit.) are also killed. At Tentsmuir Forest, Fife, also a very dry area, moderately severe attacks have developed in pines growing on formerly cultivated sites, although here the soil is acid. At Inchnacardoch Forest, Inverness, an area with higher rainfall (55 inches per annum) deaths from *F. annosus* were seen in two experimental plots thinned at intervals since 1941. The first was a 33-year-old stand of *Pinus contorta* Doug. in which the parasite was first discovered after severe windthrow had exposed partially rotted root systems. The second was a 29-year-old mixture of Scots pine and Sitka spruce in which occasional trees of both species were dying. Scattered deaths and some windthrow were seen in a 36-year-old plantation, mainly of Scots pine, at Elwy Forest, Denbigh, these having arisen after a late first thinning.

Since early stages of butt-rot are largely concealed, it is more difficult to establish their presence in first-rotation crops. A good example was discovered near an infected second-thinning stump in 23-year-old European larch at Lael Forest, Ross; *F. annosus* was already growing most rapidly in the centre of an infected root, a common feature in the development of butt-rot. A later stage was seen in slightly older Japanese larch at Craig Phadrig Forest, Inverness, *F. annosus* having recently entered the butt after heavy root infection from a stump produced 6 years earlier. In the plot of Scots pine and Sitka spruce at Inchnacardoch, mentioned above, the latter species was suffering considerable butt-rot and in one small tree infection extended 1·5 metres up the stem: root infection was traced to stumps of earlier thinnings.

Rack-cutting. In addition to removal of tree rows, providing racks for access, there may for convenience be included here other operations, such as line-thinning and widening of fire-rides, which produce continuous rows of stumps. Under appropriate conditions stump infection with *F. annosus* may be more concentrated than with thinning: thus as many as six stumps in a row have been found infected with the fungus. In East Anglia gaps often occur at intervals along racks, and in one pine plantation where racks were cut during first thinning, rows bordering racks now have four times as many affected trees as other rows. Such damage, though locally severe, is probably in aggregate far less than that arising after thinning.

Other operations. F. annosus not uncommonly becomes established in first-rotation crops before thinning, but the damage thus caused is commonly masked by the types of attack already described. Marginal infection, often spectacular, may arise when an adjacent row or plantation of conifers is felled. Infection within the crop may occur from an unexpected variety of operations. In East Anglia the commonest is the cutting out of deformed, partially suppressed or otherwise unwanted trees at the time of brashing. Usually the proportion removed is very small, about 0·3 per cent. of the total, but occasionally it amounts to as much as

6 per cent. Fortunately *F. annosus* does not become dominant in such stumps as readily as in larger ones, but small to moderate-sized disease gaps may develop around infected stumps. In one plantation it was estimated that about 2 per cent. of the pines had been killed as a result of such an operation 8 years before. An even earlier operation, cleaning, is sometimes implicated. In East Anglia pines are sometimes killed by infection from stumps of birch (*Betula* spp.), gorse (*Ulex europaeus* L.), and broom (*Sarothamnus scoparius* Wimmer). At Kessock Forest, Ross, *Tsuga heterophylla* had a 30 per cent. incidence of butt-rot at the second thinning following infection from stumps of birch cut out during cleaning.

Cutting of Christmas trees many years earlier had initiated butt-rot in 20-year-old Norway spruce at Ystwyth Forest, Cardigan, and had produced disease gaps in Scots pine of similar age at Inchnacardoch Forest. The same operation, doubtless unofficial, probably accounts for the development of one of the largest disease gaps at Thetford Chase, in a 31-year-old mixture of Scots and Corsican pines. In 1947 the gap was already 21 metres wide and by 1956 it had increased to 30 metres, involving nearly 250 trees. In these instances, by comparison with the situation at the time of thinning, the small size and relative infrequency of the sources of infection is to some extent offset by the greater susceptibility of the young crop.

Brashing itself seldom causes serious infections in pines. With vigorous trees, resin flow from any exposed living wood limits establishment of *F. annosus* infection by spores, and only with heavily suppressed, living trees is such infection common. By the time *F. annosus* reaches the base of such trees the roots are likely to have been occupied by other fungi, thus restricting or preventing its growth. In some other conifer species, however, stem infections may be expected in more vigorous trees through wounds caused in a variety of ways.

ATTACK ON HARDWOODS

It is already clear that conifers may be infected from stumps of hardwoods, such as birch. Infection and killing of hardwoods, especially on light soils, is probably more frequent than supposed. In part of the forest district Breda, Holland, 20-year-old *Alnus incana* Moench. has been badly affected after a heavy thinning 8 years earlier and 27-year-old *Quercus rubra* L. is dying in small groups as a result of cutting out bushes of *Prunus serotina* Ehrh., whose growth proved too vigorous, 5 years earlier. In East Anglia numerous deaths have occurred in 50-year-old beech (*Fagus sylvatica* L.) and birch (Plate III, fig. 1) following removal of interplanted conifers some 15 years earlier. In road-side belts and in some larger areas where pines have been underplanted with beech, *Fomes annosus* attacks have followed heavy thinning of the former. As a result the young beech has been checked in growth and sometimes killed, but damage does not appear to be serious so far.

F. annosus is recorded on a variety of native hardwoods in many European countries, including Britain, and is present as an occasional root parasite in typical mixed hardwood communities such as Monk's Wood, Huntingdon. The fungus should thus perhaps be regarded as endemic, but at characteristically low population levels, in many deciduous and mixed woodlands. Although operations such as

coppicing may favour it, the parasite normally does little damage in such situations. However, its presence is a potential source of danger to any conifer plantations established near by.

STUMP INFECTION BY SPORES

Incidence of infection. One objection to the concept of stump infection by spores of *F. annosus* is based on the apparent scarcity of its sporophores in some forest areas, and it is further assumed that the fungus is too uncommon in stumps to account for the observed incidence of disease. In forests not extensively exploited, spore infection may well be relatively unimportant and in virtually undisturbed forests, local spread along root-systems probably predominates. The incidence of stump infection by *F. annosus* is undoubtedly low throughout some forests at present, as it is in certain plantations within forests having a high average stump infection with the fungus: in neither instance, however, is frequency of sporophores a reliable guide to its extent. Formation of sporophores depends, amongst other things, upon the maintenance of a period of high humidity, which condition is fulfilled more often in thick undergrowth, in stump cavities, and under roots partly lifted by the wind (Plate III, fig. 2) than on exposed stumps. Sporophores, sometimes of considerable size, are often more or less hidden in litter: they are attached to rotted roots of trees, of conditions ranging from dead to apparently healthy. Scarcity of sporophores may thus be more apparent than real. Hidden sporophores are not necessarily much inferior to exposed ones in spore production, indeed they are less subject to drying out; moreover, the slightest air current is sufficient for dispersal, as is shown by laboratory experience with spore deposits. Field experience in East Anglia, where sporophores are rare in some areas known to be heavily infected, repeatedly shows that the incidence of stump infection can be satisfactorily determined only by sampling.

Doubt has also been cast on this concept of stump infection by the fact that although experimental thinnings of graded intensity are sometimes followed by *F. annosus* attacks approximately proportional to the intensity of thinning, in other instances they are not. Unless such experiments are performed almost simultaneously in a limited area they will not necessarily be comparable with respect to incidence of stump infection. Even if they are comparable, stump infection may be too infrequent or the soil too unfavourable for clear-cut differences in disease incidence to arise later. Apart from this, many factors other than abundance of infected stumps have been invoked in attempts to explain the relation of *F. annosus* attack to intensity of thinning. Evidence helping to resolve this problem is now available from pine plantations in East Anglia which were thinned at monthly intervals during 1946 and 1948 and in which the proportion of stumps infected with *F. annosus* was determined 12–18 months later (Rishbeth (3)). Since intensity of thinning was uniform within individual plantations, and since in several instances the soil type was not only uniform but conducive to disease development, a simplified situation exists where intensity of *F. annosus* attack may be strictly related to the proportion of infected stumps.

The plantations were re-visited in 1955, in most instances about 2 years after

FIG. 1. Fifty-year-old birch in Thetford Chase attacked by *Fomes annosus* following infection from stumps of conifers felled 15 years earlier.

FIG. 2. *F. annosus* sporophore beneath pine roots partially lifted by the wind in Elwy Forest. The lower roots were dead but the uppermost one was still alive ($\times \frac{1}{4}$).

PLATE III

the second thinning: during this operation many dead trees had been removed, but killing had continued. Since insufficient time had elapsed for crown symptoms to appear as a result of any second-thinning infections, counts of affected trees can be related to infection developing from the first thinning and might reasonably be regarded as comparable within a given plantation. For economy of time, counting was restricted to plots with contrasted *F. annosus* stump infection. Table Ia records for one plantation the percentage stump infection in monthly thinned plots of about 1 acre each and the number of dead or dying trees calculated, for uniformity, on the basis of a ten-row plot of about 700 trees. The

TABLE I. *The percentage of stumps infected by* Fomes annosus *in two pine plantations and the number of trees subsequently attacked*

Plantation A

Month of thinning, 1948 . . .	*Feb.*	*Mar.*	*May*	*June*	*Sept.*	*Nov.*
Percentage stumps with *F. annosus*, 1949	52	24	0	0	28	0
Number of affected trees, 1955 . .	60	43	7	4	31	7

Plantation B

Month of thinning, 1946 . . .	*Jan.*	*Apr.*	*June*	*July*	*Oct.*	*Dec.*
Percentage stumps with *F. annosus*, 1947	88	56	7	30	15	16
Number of trees missing from gaps, 1955	79	37	3	12	6	4

greatest contrast was found, as is commonly the case, between plots of the late winter and early summer. Slight infection in the latter derived from stumps created about 2 years before thinning, at the time of brashing. Another plantation in which the soil type was less favourable for disease development had fourteen deaths in a March plot (41 per cent. stump infection) as against three in a July plot (3 per cent.). A third plantation yielded similar data about current deaths and it was also possible to estimate from disease gaps the approximate number of trees killed before second thinning. These estimates, calculated on the basis of a ten-row plot of about 540 trees, are given in Table Ib, together with information about earlier stump infection by *F. annosus*. Here, far more trees were killed in January than in June. Under suitable conditions, therefore, it can be shown that the amount of killing by *F. annosus* is determined by the earlier incidence of stump infection by the parasite.

Stump sampling. In view of the importance of sampling both in estimating the extent of natural stump infection by *F. annosus* and the effectiveness of stump treatments in preventing it, various methods will be briefly discussed. Since trees are infected mainly from stump roots, the fullest information about potential infective capacity of a stump should in theory be obtained by excavating and sampling such roots. In practice this is too time-consuming unless detailed information is required, but fortunately analysis of the fungi inhabiting a section of stump

3–5 cm. thick, sawn off above the origin of the lateral roots, provides a fair guide to the situation in these roots. Thus, according to one set of observations, if 80 per cent. or more of the section is colonized by *F. annosus*, the fungus is likely to be present in all the roots, whereas if only 5 per cent. is colonized less than a fifth of the roots will contain it. Percentage frequency of *F. annosus* in stumps, as estimated by this method, is apparently related to the average percentage area of section colonized, the latter usually being lower by some 10–20 per cent. Wood samples taken at random from stumps may be unrepresentative because fungi tend to occupy localized sectors extending inwards from the periphery. Owing to this pattern of distribution, bark samples taken from the stump periphery (Rishbeth (3)) indicate the situation in the wood. Such samples are less bulky and easier to collect than wood samples, but the method is best suited merely to determining presence or absence of *F. annosus*.

For many purposes it is desirable to delay sampling until a year or so after felling, but information about early stages of colonization through the cut surface may be obtained by sawing off a section a few months or even weeks after felling. If on the other hand sampling is delayed more than 2 years after felling, *F. annosus* may be replaced to a varied extent by other fungi. The presence of *F. annosus* in wood or bark samples is readily determined by wrapping them in newspaper, moistening, and keeping in a container for about 1 week, although freshly colonized wood may require 2 weeks. It is important to allow access of air to the samples, since *F. annosus* conidia are formed only under conditions of good aeration. Incubation temperatures of 15–20° C. are preferable, lower temperatures requiring longer incubation and higher ones tending to favour overgrowth by *Trichoderma viride* Pers. ex Fr. Conidia may be detected with a × 10 hand lens and their presence confirmed under a microscope.

Recent observations confirm that *F. annosus* conidia are rare under natural conditions. They were found on the surface of a Douglas fir stump with an early stage of heart rot, the stump having been covered by branches after felling. They are rare or absent on stumps infected by air-borne spores, as are conidia of most fungi.

Seasonal variation. Some information is already available about seasonal variation of stump infection by *F. annosus* (Rishbeth (3)). In East Anglia the high incidence of such stump infection commonly found in January to March drops off sharply in spring or early summer: in one plantation 56 per cent. stumps were infected in April but only 9 per cent. in May. In March 1955 the incidence of *F. annosus* in pine stumps ranged from 35 to 80 per cent. and that of another polypore, *Peniophora gigantea* (Fr.) Massee, from 50 to 95 per cent. in different plantations in Thetford Chase. There is a marked tendency for such fungi to colonize stumps during winter, the dominant species varying locally. 1947 was unusual in that *F. annosus* heavily infected stumps cut during July to September, and a similar situation arose in 1955. In East Anglia, August 1947 and July 1955 were without parallel in the last 20 years in having only 0·1 inch rainfall, whereas these months have an average of over 2 inches. Figure 3 illustrates weekly rainfall during April to August 1955, and the relative abundance in stumps cut during this period

of *F. annosus* and *P. gigantea*, as estimated by the average proportion of stump section colonized. The stumps were produced in plantations thinned at intervals in a small area of forest. In all probability *F. annosus* was present in the earlier months but failed to colonize stumps owing to suppression by the more vigorous

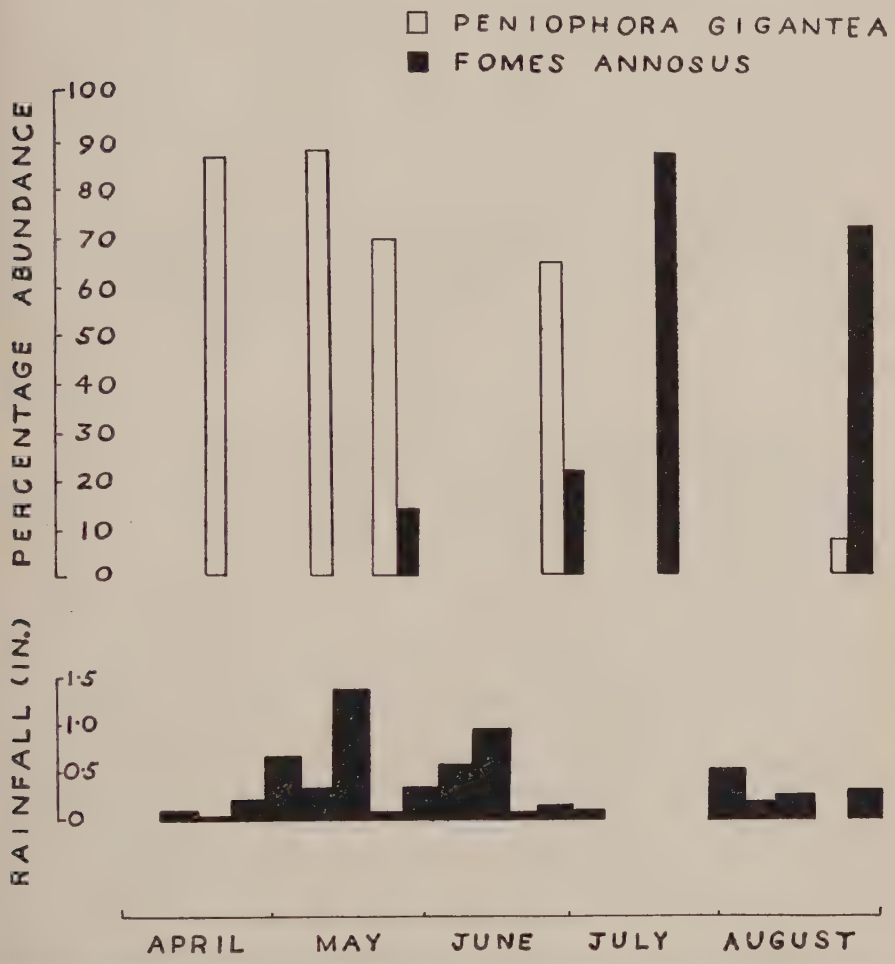

FIG. 3. Histograms showing the relation of rainfall to the relative abundance of *Fomes annosus* and *Peniophora gigantea* in pine stumps produced by thinning in Thetford Chase during 1955.

P. gigantea. The onset of very dry weather in late June and July was accompanied by a marked increase in the abundance of *F. annosus* in stumps, probably because the sporophores of this fungus are more drought-resistant than those of *P. gigantea* and other competitors.

Observations on the air spora in plantations confirm this. Petri dishes of malt agar were exposed for 10 minutes in a vertical position, facing into the wind, either at stump level, for recording discharge from *F. annosus* sporophores, or at a

height of 60 cm. for random exposures. Table II summarizes data obtained from plates exposed at different times of the year and incubated for 10 days at 22·5° C. Spore discharge by *F. annosus* was not checked by the prevailing drought in early August 1955, and may well have been greater than in March, owing to the higher temperature. Earlier observations showed, however, that with very exposed sporophores, discharge tends to be checked by dry weather. Random exposures indicate that spores of *P. gigantea* were more frequent than those of *F. annosus* in March and October 1955, but that the latter predominated in August 1955. In August 1956, probably because of the much wetter summer, other basidiomycetes were more abundant than *F. annosus*. Since some of these fungi, as for example *Hypholoma fasciculare* (Huds.) Fr., colonize pine stumps, their competition may partly account for the varying degree to which *F. annosus* is suppressed in stumps during all except very dry summers. Sporophores of *F. annosus*, *P. gigantea*, and *Stereum sanguinolentum* (A. & S.) Fr., collected after a spell of intensely cold weather, produced appreciable spore deposits at 4° C. The dominance of such fungi in stumps during late winter may derive not only from this ability but from the rarity of frost-susceptible sporophores of agarics and perhaps also from the relatively low incidence of non-basidiomycetes in the air spora at this time. Confirmation of the belief that development of sporophores near the ground does not imply lack of efficiency in dispersal is provided by the trapping of *F. annosus* spores at a height of 60 cm. although they were often being discharged at ground level only a short distance away.

TABLE II. *Fungi developing on malt agar plates exposed in pine plantations*

		Average number of colonies per plate from				
		Random exposures				*Exposures near* F. annosus *sporophores*
Date	*Air temp.* (°C.)	F. annosus	Peniophora gigantea	*Basidiomycetes other than* F. annosus	*Non-basidiomycetes*	F. annosus
15 Mar. 1955	9	0·2	0·8	1·5	2·6	5·0
1 Aug. 1955	21	0·4	0·1	0·1	20·9	12·4
28 Oct. 1955	6	0·1	0·7	2·3	7·5	5·8
3 Aug. 1956	18	0·3	0·1	0·9	16·2	9·0

Only a few factors influencing stump infection have been considered here and a great deal still remains to be discovered. The main practical point is that the incidence of stump infection by any given fungus, such as *F. annosus*, is largely unpredictable.

Build-up of infection. The prevailing tendency appears to be towards a greater occurrence of stump infection by *F. annosus*. Already by 1946 the incidence of this fungus in first-thinning stumps, cut at monthly intervals, averaged 28 per cent. in a plantation on the outskirts of Thetford Chase. A first thinning of pine in

part of Ampthill Forest, Bedford, was followed by a stump infection of the order of 10 per cent. although this was predominantly a hardwood area. Few estimates have been made elsewhere, but in North Scotland the situation was investigated in first-rotation crops of larch during 1955. Where stumps of only the first thinning were present (two plantations), the proportions infected with *F. annosus* were 0 per cent. and 2 per cent. respectively; where stumps of both first and second thinnings were present (three plantations), the proportions were 3 per cent., 2 per cent., and 10 per cent. The distance from former woodland never exceeded about a mile, and the great majority of new British forests must be as close as this to potential sources of infection. Once stumps become infected and sporophores are produced the chance of further air-borne infection is considerably increased, for it is no longer dependent on spore dispersal from a distance. At the same time, as root disease becomes more prevalent, a greater number of stumps will become infected from roots already containing the parasite. The main reason for the current tendency for *F. annosus* to become more widespread is undoubtedly the greatly increased incidence of regular thinning.

THE PRESENT SITUATION IN EAST ANGLIA

Before commenting on recent developments in East Anglia it may be well to restate briefly some of the factors affecting severity of *F. annosus* attacks. The frequency and degree of concentration of infected stumps is clearly important and is related not only to the type of operation producing the stumps but to the proportion becoming infected. The amount of root infection developing around the stumps will depend on their age, the vigour of *F. annosus* declining, and its replacement by other fungi increasing with time. Amongst other factors are the prevalence of root contacts and the part played by the root surface microflora in controlling infections. The subsequent type of attack and its intensity are determined by host resistance, itself influenced by the age and species of tree and by factors of soil and climate. The multiplicity of situations arising from such an interplay of factors, even in a small forest, needs little comment. It may be noted, however, that highly susceptible plantations may entirely escape attack because conditions for stump infection were not fulfilled, perhaps on successive occasions: this situation may cause confusion in surveys.

Disease assessment. Severity of attack by killing may be assessed in many ways, of which three will be briefly discussed. Firstly, it is possible to make a general survey of all plantations in a given area, scoring disease severity by some standard system. This operation can be repeated at suitable intervals to give a general picture of disease development throughout the area. However, scoring may involve serious subjective errors of assessment and is complicated by the fact that in plantations over 20 years old the number of dead trees depends on the interval since the last thinning, when most or all were removed. In theory such surveys could be supplemented by aerial photographs recording the size and distribution of disease gaps. Thus some photographs taken in 1946 during an aerial survey show characteristic *F. annosus* outbreaks: at Swaffham Forest, for instance, over forty disease gaps are visible in some plantations. Early stages of attack are more difficult to discern and it

is probable that the chief value of such photographs is for recording the development of particular outbreaks already well under way.

Secondly, more detailed surveys may be made of representative plantations, especially where the history of forest operations is well recorded. For young second-rotation crops the proportion of trees killed gives a fair indication of the severity of early attacks (Rishbeth (4)). With first-rotation crops, in which infection foci are initially more scattered, such estimates are tedious, involving much larger counts, and are subject to error through earlier removal of dead trees. For this reason also it is often difficult, merely by inspection, to assess the present rate of killing. A useful supplementary method of assessment is to calculate the growth-rate of *F. annosus*: this may be done by measuring the extent of its spread on living roots from stumps of known age.

TABLE III. *The percentage loss by volume in thinnings at Thetford Chase through killing by* Fomes annosus

Thinning	*Total no. of plantations*	*No. of plantations with percentage loss by volume in the groups*						*Average percentage loss*
		⟨ 2·0	2·1 –5·0	5·1 –10·0	10·1 –20·0	20·1 –30·0	⟩ 30·1	
1st . .	28	28	..	..	..	..	..	0·3
2nd . .	75	36	26	7	7	2	3	5·9
Subsequent	13	..	1	2	3	5	2	19·5
Total .	116	58	27	9	10	7	5	6·1

Thirdly, data can be collected from thinning records to obtain the percentage loss in volume due to killing by *F. annosus*. Such estimates have the merit of being reasonably objective and of providing some indication of economic loss. Errors arise from inclusion of some suppressed trees and other material in the *F. annosus* volume, but the fact that this figure is very low for first thinnings suggests that these errors are small. They are in any case offset by the occasional removal between thinnings of trees killed by *F. annosus*. Indeed it may be claimed that the figures underestimate loss from *F. annosus* since they fail to reveal any reduction in volume caused by severe root infection. Table III gives data from 116 plantations, mostly thinned during 1955–6 and located in Thetford Chase (106) and Swaffham Forest (10). The table records the number of plantations falling into various groups of percentage loss by volume. The sample is of reasonable size, constituting about one-fifth of the total area thinned during the period, but the ratio of first thinnings to later ones is a little low. Thinnings subsequent to the second occurred predominantly in plantations on alkaline sites, and though the average loss is representative in the sense that earlier plantings were commonly made on such sites, it may prove an exaggerated forecast of loss from such thinnings in the future. The figures nevertheless provide impressive evidence of the build-up of *F. annosus* in plantations and it seems that the average loss from all thinnings, probably now in the region of 5 per cent., will increase for some years as the proportion of early thinnings declines.

It should be noted that such figures greatly over-estimate (about sixfold) the incidence of deaths in the plantation, as might be expected from the fact that nearly all dead trees are removed. Thus in one plantation the proportion of deaths from *F. annosus* at the time of second thinning was estimated to be 2·4 per cent., whereas the thinning loss was 14 per cent. Where records have been kept over a sufficient period it is possible with a given plantation to follow changes in *F. annosus* loss from one thinning to the next. In one instance the loss increased from 0·4 per cent. at the first thinning to 7·4 per cent. at the second, and in another there was a more spectacular increase from 1·7 per cent. at the second thinning to 34·7 per cent. at the third.

Progress of attacks. Information of this kind has been supplemented by visiting selected plantations and this has often provided a more complete picture of the initiation and subsequent development of *F. annosus* attacks. It is now clear that these occur whenever certain conditions are fulfilled and did not first arise as a result of a number of unusual seasons, as was earlier suggested. However, the earlier outbreaks tended to be more severe because the first operation producing stumps, commonly 'wolfing', was often carried out in plantations 14–16 years old whereas now the first cutting commonly occurs when they are 18–20 years old.

In several instances measurements were made to determine whether the rate of advance by *F. annosus* had changed in recent years. In two plantations the growth-rates measured in 1947, each 0·5 metres per year, were virtually unchanged in 1956: *F. annosus* had advanced steadily in one plantation for 18 years and in the other for about 25 years. Similarly unaltered but much faster growth-rates, about 1·0 metre per year, were found in 30-year old pines bordering, respectively, a felled woodland and a heavily thinned experimental plot. Disease gaps in such situations and also alongside racks are often characterized by a particularly rapid spread of the parasite, as compared with gaps on comparable sites originating from scattered thinning stumps. This probably results from the high concentration of infected stumps: the fungus advances from the outset on a wide front, infecting a considerable proportion of the roots of adjacent trees. These trees die more rapidly than they would after a few infections derived from a thinning stump, and the initial momentum of the attack appears to be maintained. Disease gaps in other first-rotation crops were extending more slowly than before or had ceased to enlarge altogether. As might be expected from earlier observations, this tendency was pronounced on acid soils but also occurred on some alkaline ones, especially those of slightly heavier texture. It is now evident that site affects the eventual stability of disease gaps more closely than tree age, and earlier statements about stability (Rishbeth (4)) therefore need modification. Though disease gaps on acid soils tend to become stabilized by the time trees are 25 years old, they continue to extend for longer on alkaline soils, particularly where chalk is near the surface. On such sites, trees are still rapidly dying in some of the oldest existing plantations, aged 34 years.

A more encouraging situation is to be found in second-rotation crops. It was earlier thought possible, from the high mortality of young trees, particularly on alkaline sites, that *F. annosus* attacks would become so crippling as seriously to

prejudice prospects of a reasonable timber yield. This impression was confirmed by the recent discovery of a 10-year-old plantation in which 31 per cent. of the pines had already been killed. A survey of older plantations showed however that on many acid soils killing by *F. annosus* virtually ceases by the age of 15 years, and that former disease gaps are hard to locate after another 10 years. On alkaline soils killing becomes less frequent by the age of 15 years and commonly ceases after 25 years. In plantations on such soils the average width of disease gaps is often 5–7 metres as compared with gaps about 14 metres wide and of more recent origin in first-rotation crops. The present comparative freedom from root disease of a 27-year-old plantation on former woodland is shown by the fact that trees killed by *F. annosus* constituted only 2 per cent. of the total volume at the second thinning. Nine years earlier, by contrast, nearly 20 per cent. of the trees had been killed, as is typical of alkaline sites. It is true that in these plantations growth tends to be very uneven in the early stages and is coarse around disease gaps, but these effects assume much less importance with age. It should be stressed that *F. annosus* may readily be reintroduced into such plantations, as for instance by thinning.

This tendency for disease gaps on former woodland sites to become stabilized relatively soon is probably connected with the fact that for some time after planting *F. annosus* spreads mainly as a result of chance contacts between young tree roots and stump roots. Only later, perhaps after about 10 years, are root contacts sufficiently common in the new crop to allow rapid radial spread of the disease, but by this time the marginal trees, probably benefitting from a period of reduced competition on one side, are usually able to check the parasite. In addition, the vigour of *F. annosus* in old stump roots has declined. It is characteristic of such attacks, which maintain their momentum only very locally, that survivors commonly occur within the gaps. The position differs greatly in crops where root contacts already abound at the time of infection, as after first thinning: here host-resistance, the chief barrier to rapid spread of *F. annosus*, is doubtless lowered by intense competition between trees. Under such conditions advance of the parasite is often rapid and survivors are rarely to be found within disease gaps, except towards the edge of plantations where competition is less intense. This implies that all types of trees, from dominant to partially suppressed, may be killed outright. There is little evidence that *F. annosus* preferentially attacks fast-growing trees in a particular stand, as is reported sometimes to occur with butt-rot (Arvidson (1)). However, there is a tendency for fast-growing crops as a whole to suffer more serious killing attacks than slow-growing ones, but this arises at least in part from association of the former with alkaline and cultivated soils, of which the effects on *F. annosus* itself cannot be disregarded.

Sites replanted after fire provide conditions intermediate between those just described. An interesting contrast is shown by two such plantations of similar age and history but on different soil types. Between 1947 and 1956 the proportion of dead trees increased from 17 to 33 per cent. in one on a very alkaline soil but showed no appreciable increase from 10 per cent. in the other on an acid soil. The average width of disease gaps in the two plantations was 11 metres and 3 metres respectively.

It is difficult to predict how *F. annosus* attacks will develop in the future. The tendency for attacks to subside on old woodland sites, in the absence of renewed infection, is an encouragement for replanting but will not greatly affect the immediate issue since the area involved is only about one-fifth of the total. Developments in plantations on former arable and alkaline grassland, perhaps amounting to two-fifths of the total area, will, however, affect the situation considerably: the average loss from *F. annosus* is bound to increase in them for several years, but there is a reasonable expectation that attacks in some will soon become stabilized. As far as can be foreseen, average thinning losses in plantations over 25 years old on acid soils should not exceed 4 per cent. Stump creosoting should help to confine the parasite to existing disease patches in affected areas and should limit its dispersal to healthy plantations.

THE SITUATION ELSEWHERE

In some respects the situation which has developed in East Anglia has a bearing on that in other parts of Britain. Particularly in drier areas, comparable but less intense attacks have already developed in some forests. Since the extent both of killing and of butt-rot is influenced by the amount of initial root infection, the relative importance of various forest operations for initiating killing (p. 69) may also hold for butt-rot, whose relation to the former has been discussed elsewhere (Rishbeth (5)). With butt-rot, however, the effect of any particular operation is far more difficult to determine since infections often progress slowly over long periods: thus the condition of a tree near maturity may result from a series of infections, arising from successive operations. Similarly, with species liable to butt-rot, infection from stumps of a previous crop often leads to more serious damage than with pines, where root infections of this origin tend to become stabilized relatively early. The tendency for stump infection with *F. annosus* to become more widespread has already been noted, and in new areas the pathogen may well build up steadily, if not as fast as in East Anglia.

With respect to other countries, an impression exists in parts of Europe and North America that damage caused by *F. annosus* has increased in recent years, although it is difficult to obtain factual information on this point. This may well be so, for forest operations have often been intensified in more accessible areas and forests formerly regarded as too remote are now being exploited. It can be argued that under these conditions attacks tend to be severe largely because *F. annosus* has frequent opportunities for colonizing stumps: in natural or semi-natural forests, by contrast, such opportunities arise infrequently, for instance as a result of fire or storm damage. An important additional factor in the increased severity of *F. annosus* attacks is the establishment of new plantations on soils disturbed by cultivation.

ECONOMIC LOSS

The economic loss caused by *F. annosus* has long been the subject of speculation, few estimates of its extent being available. For East Anglia, a very approximate estimate of the direct loss through killing may be obtained from timber yields of

current thinnings. On the basis of an estimated loss for all thinnings of 5 per cent., the average yearly loss in Thetford Chase is just under £1 per acre. Losses in second and third thinnings on alkaline sites may exceed £5 per acre, however.

Greater losses resulting from butt-rot have been recently recorded for rather older crops in Sweden. Thus Rattsjö and Rennerfelt (2), by felling small sample plots of Norway spruce, estimated that the average volume of wood decayed was 14·6 per cent., with a corresponding economic loss of 22·9 per cent. The second figure is larger because rot chiefly affects the most valuable basal part of the stem. Data from three sample plots, containing pure or almost pure naturally regenerated Norway spruce are quoted in Table IV: losses have been converted from

TABLE IV. *Losses through butt-rot in some Swedish stands, mainly of Norway spruce*

*Age**	*Percentage of trees rotted*	*Percentage of volume decayed*	*Loss in pounds per acre*
40–50	45	7·3	43
60–70	59	11·9	49
60–70	86	19·5	88

Data from Rattsjö and Rennerfelt (2).
* Age of the majority of trees in uneven-aged stands.

kroner per hectare to pounds per acre. Arvidson (1) made observations, also by felling Norway spruce, of which the most interesting relate to damage from *F. annosus* in a 65-year-old stand. Here 41 per cent. of the trees were decayed and primary damage, directly attributable to decay, was estimated to have caused losses per acre of £26 by 1947 and £38 by 1955. Secondary damage resulting from poorer growth and impaired stem form was greater, causing additional losses per acre of £42 and £51 in the 2 years respectively. Within a period of 5 years, therefore, the total loss per acre rose by over £20. As Arvidson points out, root rot is far more serious economically than has earlier been assumed.

CONTROL

Results of earlier experiments. The effect of various stump treatments on stump infection by *F. annosus* has already been reported (Rishbeth (6)). Of experiments laid down during 1947–9, three have provided information about subsequent tree infection. In the first, stumps were extracted after rack-cutting in an 11-year-old pine plantation on former arable (pH 5·8). Some 8 years later *F. annosus* had killed very few trees alongside such racks although a little infection had started from another source. By the side of racks cut at the same time, but from which stumps were not removed, over twelve times as many trees had been killed.

In the second experiment, the following stump treatments were carried out during first thinning of 20-year-old Scots pines growing on former arable (pH 8·0): (1) creosoting, (2) painting, (3) covering with soil, (4) no treatment—control, (5) extraction by winch. Treatments (1) to (4) were repeated in three blocks along the length of the plantation, plots each having sixteen rows and an average area of

2·5 acres. Owing to the difficulties encountered, treatment (5) was carried out only once, stumps in another plot destined for this treatment being creosoted instead. Plots were separated by racks in which the two rows of stumps received the same treatment as those in the preceding plot. The proportion of stumps infected with *F. annosus* in the various plots was estimated after about 1 year and the number of dead and dying trees was counted after 7 years, just over 1 year after the second thinning. This latter interval was too short for crown symptoms to have appeared as a result of any infection from second-thinning stumps. Table V records the proportion of stumps infected with the parasite in the various plots and the number of visibly affected trees in fourteen rows, the rows bordering racks being omitted for sake of uniformity.

TABLE V. *The effect of various stump treatments on colonization of pine stumps by* Fomes annosus, *and on subsequent killing of pines*

	Averages from all plots				
(*a*) Stump treatment, 1947–8 . . .	(1)	(2)	(3)	(4)	(5)
(*b*) Percentage stumps infected, 1949 . .	4	3	54	36	.
(*c*) Number of trees visibly affected, 1954 .	5	5	45	30	5

Individual plots in blocks:

	A					B					C			
(*a*)	(1)	(2)	(3)	(4)	(5)	(1)	(2)	(3)	(4)	(1)	(1)	(2)	(3)	(4)
(*b*)	3	3	90	75	.	5	3	32	17	.	5	3	41	15
(*c*)	3	1	62	63	5	8	6	34	11	4	5	7	39	15

Stump treatments: (1) Creosoting, (2) Painting, (3) Covering with soil, (4) None, (5) Extraction.

The number of trees recently affected by *F. annosus* in the various plots corresponds closely with the proportion of stumps infected after the first thinning and, from the known behaviour of the fungus, this must also indicate its distribution up to the time of second thinning. That a breakdown of stump protection was not wholly responsible for the appearance of affected trees in treatments (1) and (2) is suggested by the fact that their incidence was actually lower in block A than in blocks B and C, despite a higher natural stump infection with *F. annosus* in the former. It was established that a small amount of infection had arisen prior to thinning, through cutting out trees during brashing. The efficiency of creosoting, as judged by the proportion of stumps in which infection by *F. annosus* was prevented, averaged 89 per cent. in the four plots and was rather higher in block A. Efficiency as judged by the subsequent saving of trees was similar. Treatment with creosote or paint was at least as effective as the more difficult and costly stump extraction. Further evidence was provided by rack margins in which trees were protected to varying extents. Where stump protection or removal, i.e. methods (1), (2), or (5), had been carried out on both sides of a row, within the plot and in the rack, an average of two trees per row were affected with *F. annosus*. Where stumps had been protected on neither side, by contrast, an average of sixteen

trees per row were affected. This result occurred despite a partial breakdown of stump treatment in the racks, which probably resulted from subsequent damage to stumps by lorries.

The third experiment was also carried out during first thinning of Scots pine on alkaline former arable. Two treatments (1) application of tar/creosote, 2 : 1, (2) painting, and (3) an untreated control being replicated in four blocks. In three blocks infection of untreated stumps with *F. annosus* was high enough (average 17 per cent.) to give some differences in subsequent tree killing, but unfortunately these differences were somewhat obscured by infection from trees cut out during brashing, 2 years before thinning. After correction for loss from this source, the average number of trees per ten rows affected by *F. annosus* in the various treatments 5 years later was (1) 20, (2) 4, and (3) 37. Painting stumps was 89 per cent. effective against subsequent attack but the tar/creosote treatment for some reason virtually failed.

These results confirm the hypothesis that in East Anglia most root disease caused by *F. annosus* in first-rotation crops is to be attributed to earlier stump infection by wind-borne spores. They also support the contention that the incidence of such disease can be considerably reduced by treating stumps with a suitable protectant directly after felling. It is estimated, for instance, that in the second experiment, where loss through *F. annosus* was 10 per cent. at the second thinning, nearly half of the dead trees came from block A and that of these well over 90 per cent. came from plots in which stumps had not been protected.

Large-scale stump creosoting. In 1952 the Forestry Commission initiated stump creosoting in East Anglia for first thinnings at sites where *F. annosus* attacks were liable to be severe, and in 1954 this treatment was extended to subsequent thinnings and to plantations on a wide range of sites. In 1955 an attempt was made to determine its effectiveness in preventing stump infection with *F. annosus*. In twelve plantations on Thetford Chase, thinned during March to August, stumps were left uncreosoted in a narrow strip. About 1 year later samples were collected from these and from adjacent creosoted stumps by sawing off a section from the top, care being taken to avoid any existing patches of root disease. The results obtained by examining stump samples from eight of these plantations, in which natural stump infection with *F. annosus* exceeded 10 per cent., are given in Table VI. Control of such infection was moderate to good, its efficiency averaging 81 per cent. when based on the reduced average area of stump section colonized and 61 per cent. when based on the proportion of stumps in which infection was entirely prevented. The former figure may well be a closer estimate of efficiency in preventing subsequent infection, since the area of stump section occupied by *F. annosus* is related to the proportion of stump roots colonized. The latter figure is, however, more comparable with the figure of 89 per cent. quoted for an earlier experiment. Creosoting similarly reduced the incidence of *P. gigantea*, which was often more abundant than *F. annosus* in untreated stumps. A further encouraging observation was that the vigour of both species in creosoted stumps was often much lower than in untreated ones, possibly owing to greater competition from other fungi (p. 88).

Causes of partial failure. Further investigations were directed towards determining why large-scale stump creosoting was rather less effective than that performed in the earlier experiment. Investigations are not yet complete, but there are apparently several factors which will be considered in their probable order of importance. Firstly, the type of creosote differs from that used in the experiment, the new type apparently not affording as good protection against colonization by basidiomycete spores. This is particularly evident from results of creosoting in the second plantation listed in Table VI. Shortly after thinning in late June natural stump infection by *P. gigantea* markedly decreased whereas that by *F. annosus* greatly increased, and it is significant that the efficiency of creosoting was 88 per

TABLE VI. *The occurrence of* Fomes annosus *in creosoted and uncreosoted stumps in eight pine plantations*

*Percentage abundance**		*Percentage frequency*†	
Not creosoted	*Creosoted*	*Not creosoted*	*Creosoted*
14	2	32	5
22	14	35	42
87	19	100	58
72	8	89	44
19	1	30	7
58	1	80	10
54	4	65	10
24	6	44	17

* Based on average area of stump section colonized.
† Based on presence or absence in stump section.

cent. for the former species but only 36 per cent. for the latter. This tendency for stump protection to break down under conditions favouring heavy infection by *F. annosus* at the time of felling or shortly afterwards was confirmed experimentally. Freshly cut stumps were heavily creosoted and inoculated with *F. annosus* spores 2–3 weeks later: in several instances small infections developed, showing that protection was incomplete. Preliminary tests with other types of creosote and a tar/creosote mixture suggest that these give better protection.

Secondly, the amount of creosote applied to stumps in the course of large-scale creosoting tends to vary. In a plantation where control, based on the frequency of *P. gigantea* in stumps, was only 58 per cent. effective creosote penetration was poor and the stumps had probably received a light application. A subsequent experiment showed that a very light application of the creosote in current use gave virtually no protection against natural infection by *P. gigantea* whereas a heavy application gave almost complete protection. The extent to which this situation arises with other types of creosote is not known.

When stump protection was first suggested the importance of immediate treatment was stressed. In practice the interval between felling and treatment was found to vary considerably, although it was seldom more than 8 hours. With

pines, resin exudation from the stump surface may prevent creosote entering the wood. In one plantation of Corsican pine, creosoted stumps actually contained more *P. gigantea* than uncreosoted ones. The latter had been extensively colonized by *Gliocladium* sp., apparently restricting infection by *P. gigantea*, whereas in the former resin had interfered with creosote penetration: early colonization by *Gliocladium* had been prevented but *Peniophora* infections had occurred later. Resin exudation of itself seldom prevents colonization by *F. annosus* and *P. gigantea*: these enter through minute areas not covered by resin. Experiments carried out during thinning of 22-year-old Corsican pine, when resin flow from stumps was only moderately rapid, showed that creosote penetration was excellent when a heavy application was given immediately, moderate when it was delayed for 20 minutes and poor when it was delayed for 3 hours. Resin flow was markedly suppressed by immediate application. Where resin exudation occurs, therefore, rapid stump treatment is essential; and this is in any event desirable in view of the possibility that spores alighting on the surface may be carried some distance into the wood by rainfall. Further experiments are required to determine the maximum period for which it is safe to delay treatment under various conditions, but with creosote this period seems unlikely ever to exceed 8–12 hours.

Finally, current stump creosoting breaks down to a limited extent through incomplete application. This is particularly liable to occur with larger trees when a jagged projection is left on the stump or when the bark is torn away below the stump surface: such irregularities may not be adequately creosoted. Mechanical damage to stumps after treatment, as for instance in racks, has already been mentioned.

Discussion of control measures. At this stage mention should be made of interesting studies in part of the forest district Breda, Holland, concerning the effect of various soil treatments on tree growth and *F. annosus* attack (van Goor (7)). Many experimental sites formerly bore pines, and it is thus hardly surprising that with no treatment, infection from stumps regularly led to killing in plantations up to 10 years old: complete removal of stumps eliminated such killing. In plantations 20–40 years old the incidence of *F. annosus* attack arising after thinning depended on the amount and duration of previous soil treatment. Virtually no attacks developed on untreated sites, earlier infection from old stumps presumably having subsided in the manner already described for East Anglia. About 22 per cent. of the plantations were attacked after stump removal and partial soil preparation, achieved mainly by ploughing combined with harrowing or digging, which mixed the A- and B-horizons. More severe attacks were recorded after complete tillage followed by 1 year's growth of lupins (66 per cent. stands affected) and after 2–4 years' agricultural usage (100 per cent. affected).

Besides showing the deleterious effect, with respect to *F. annosus* attacks, of even short periods of cultivation, these results are of interest in revealing the possibility that disturbances to the soil profile, for instance through stump removal and subsequent levelling, alone may predispose a plantation to attack. This consideration, apart from expense, could constitute an objection to stump removal as a means of controlling *F. annosus*; but effective stump protection later

would largely offset any disadvantage with respect to increased susceptibility. (This latter point may also apply where cultivation is employed to improve early growth of conifers.) Apart from this, however, it is arguable that killing attacks originating from old stumps can often be ignored in replanting, since they subside. Where the second-rotation crop is susceptible to butt-rot, by contrast, ways of reducing initial infection assume far greater importance.

The present cost of stump creosoting in East Anglia, about 10*s*. per acre, is lower than the figures given for earlier experiments (Rishbeth (6)). Costs of labour and materials are in the approximate ratio of 4:1. Since thinning is carried out at intervals of about 5 years, the annual cost of the treatment is about 2*s*. per acre, much lower than the estimated average loss through *F. annosus* of about £1 per acre. In fact the cost of stump treatment is so low that it will almost certainly prove economically justifiable as a means of protection against butt-rot, at least in some circumstances. However, a very real difficulty arises with butt-rot, and to a lesser extent with killing: the extent of damage becomes evident only after many years, and by the time it is apparent that stump treatment would have been justified, the opportunity for control will have passed. In Britain, there appears to be a good case not only for estimating the extent of current damage from butt-rot but for commencing stump treatment in areas where existing damage in second-rotation crops indicates the probability of serious attack in nearby first-rotation ones.

Before an operation such as stump treatment is carried out on an extensive scale it is desirable to consider not only its economic but its wider implications. The possibility exists that it might adequately control *F. annosus* but have serious long-term disadvantages. The two components of the forest community most affected are stump fungi and insects. With the former, stump treatment acts mainly in the direction of deflecting succession away from primary colonizers, which characteristically break down lignin. There is evidence that other wood-destroying fungi enter the stump later and thus decay is delayed rather than prevented: in fact, the situation in treated stumps resembles that naturally arising in stumps exposed during summer months in East Anglia. The problem raised by treating stumps whose roots are already infected by *F. annosus* needs further attention but may be considered in light of the fact that the fungus becomes dominant in a high proportion of such stumps even when untreated. In general, treatment of these stumps may be deleterious in some instances, but only where it effectively blocks entry of other fungi. On balance, stump treatment seems unlikely to have any serious disadvantages.

With stump insects the main danger presumably arises from any large increase in population of certain important species, such as *Hylastes ater* Payk. This might conceivably happen if treatment in some manner increased the amount of available food, but with the present creosoting death of stumps is usually as rapid as in the case of untreated ones. Entry of *Hylastes* occurs just as soon and is not confined to the cut surface. As far as can be predicted, stump treatment is unlikely to have any major effect on the population of such insects.

Recent research on stump treatments. In East Anglia alone current losses from

F. annosus justify continued research into stump treatments. The ultimate aim is to discover sufficient alternatives to fit varied situations and to understand their mechanisms in relation to normal fungal succession in stumps, which is at present insufficiently known. At least in theory, stumps might be protected in several ways, including (1) exclusion of all fungi from the cut surface, the stump being colonized later by other means, (2) selection of microflora on a basis of varied tolerance to the protectant, the woody substrate being little changed, and (3) encouragement of widely varied microfloras, resulting from radical alterations to the substrate. In practice such effects are probably combined in various ways. Situation (1) often occurred in the experiment described earlier (p. 83): painted or creosoted stumps tended to remain alive longer than untreated ones and were eventually often colonized by *Tricholoma rutilans* (Schaeff.) Fr. Situation (2) possibly occurs to some extent in the current creosoting: primary basidiomycete colonizers such as *F. annosus* and *P. gigantea* are usually excluded and many other fungi, including the ascomycete *Ophionectria cylindrospora* (Sollm.) Berl. & Vogl., enter stumps fairly soon. Stumps quickly die but do not decay very rapidly owing to the initial exclusion of wood-destroying fungi. However, these effects may partly be due to a rapid killing of the surface tissues by creosote, as suggested by the suppression of resin flow.

Situation (3) has been achieved by certain experimental treatments, notably with concentrated salt solutions: thus *Botrytis cinerea* Fr. often becomes dominant in pine stumps treated with 20 per cent. sodium chlorate and *Trichoderma viride* in stumps treated with 40 per cent. ammonium sulphamate. With the latter resin production by the stump is markedly suppressed and a copious growth of the fungus may develop on the surface within a few months. Preliminary results indicate that these substances, and also half-strength commercial formalin, are often effective against natural stump infection by basidiomycete spores. The following tentative conclusions may be drawn about their mode of action. A freshly cut, untreated wood surface is colonized readily by spores of many basidiomycetes but slowly by spores of common mould fungi. Killing the wood surface by any means often allows rapid colonization by a variety of fungi, particular chemicals tending to encourage growth of specific fungi. The stump surface, except for the phloem, appears to be relatively deficient in nitrogen, and addition of ammonium salts greatly stimulates growth of some fungi. The initial effect of treating a stump with concentrated ammonium sulphamate, for instance, is to encourage rapid colonization by *Penicillium* spp., the spores of which are commonly scattered over the stump surface by sawing: with untreated stumps such growth is at first confined to the phloem. Increased fungal competition in the wood tends markedly to restrict growth of basidiomycetes. Later, fast-growing fungi such as *T. viride*, and to a lesser extent *B. cinerea*, tend to become dominant, although the former is not so abundant in stumps treated with non-nitrogenous compounds.

From the practical viewpoint, alteration of stump tissues by chemical means, with subsequent natural infection by ubiquitous fungi such as *T. viride*, is far preferable to stump inoculation, as in experiments with *P. gigantea* reported

earlier (Rishbeth (6)). Where stump infection by air-borne spores of *F. annosus* is the main or only issue, such chemicals seem unlikely to supersede creosote as protectants. The approximate cost per acre, excluding labour, of materials used in recent experiments is as follows: creosote 2*s.* 6*d.*; paint 53*s.*; formalin 10*s.*; sodium chlorate 4*s.* 6*d.*; and ammonium sulphamate 29*s.* However, where root infection by *F. annosus* is known to be prevalent before felling and it is considered desirable to reduce the intensity of attacks in the early life of a plantation, stump treatment with a suitable salt solution might prove valuable. Air-borne infection, possibly a major factor even in these situations, would be controlled and in addition the active growth of fungi such as *T. viride* might well prevent a major spread of *F. annosus* within the stumps from portions already infected. An experiment to test this possibility has been set up.

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FOREST AND RANGE POLICY IN THE UNITED STATES

Review by BARRINGTON MOORE

DANA's *Forest and Range Policy*[1] is not to be confused with the late William B. Greeley's *Forest Policy*. The two books cover different fields, which, however, converge somewhat toward the end of Dana's book. Greeley deals with present policies in practically all countries of the world which have such policies. Dana, on the other hand, gives an historical analysis of the conditions underlying the development of changing policies in the United States only from colonial times to 1955. In his book the interaction between personal attitudes in a new environment, rich in natural resources to be had for the taking, and an inexperienced government, is both interesting and instructive to follow. Professional foresters in Great Britain, like foresters the world over, find it profitable as well as enjoyable to read about forestry activities in other countries. They may have the opportunity of seeing some of those countries for themselves, who knows?

In the colonial period the reservation of pine trees for masts for the Royal Navy, by marking with a 'broad arrow', is said to have been one of the irritations which brought about the American Revolution. Furthermore, the measure was ineffective because the trees were cut to such an extent that the Navy was severely handicapped for lack of masts. Yet, after independence was secured, the forests of live oak reserved for the new American Navy, suffered the same fate.

After the Revolution the 13 states ceded to the central government for the benefit of all the states the land each state claimed beyond its borders. These 233 million acres became the first part of the public domain. Soon the Louisiana purchase added 523 million acres more in the rich Mississippi valley, and later purchases brought the total area of the public domain up to 1,422 million acres, exclusive of Alaska's 365 million which have mostly been handled by special legislation different from that considered in this book.

Under the Constitution, Congress has full power to sell, give away, or retain the public domain for such purposes and by such methods as it sees fit. The story of the amazing way in which this power was used, or rather one should say misused, is told in this book. Of the total 1,422 million acres only 411 million, or 29 per cent., are left, and that mostly arid waste land and ruined range that nobody wants.

Congress had two main objectives, first to get revenue, and second to place the land under the plough as quickly as possible. The first objective yielded only a minute fraction of what the resources were worth. The second objective was attained, but at the expense of enormous waste, which fostered an attitude that unfortunately persists to this day.

[1] *Forest and Range Policy. Its Development in the United States*, by Samuel Trask Dana. McGraw-Hill Publishing Company Ltd., McGraw-Hill House, 95 Farringdon Street, London, E.C. 4, 1956. Pp. 455, price 49*s*.

The forest was an encumbrance which had to be cleared so that the land could be cultivated. The farms and towns required large quantities of timber for housing and other purposes. But the forests were 'inexhaustible', so people thought in those days.

It is almost unbelievable that, with the urgent need for timber on which the rapidly growing country depended, Congress provided no way by which that in the forests of the public domain could be sold. So it had to be stolen, and the land with it. The practice was so widespread that it became perfectly respectable. After the forests in one region were cut out, with no thought for the future, and burned over, the lumber industry moved on to another region and repeated the process.

Contrast this situation with Canada (not mentioned in this book) where the timber on government land, comprising most of the forest land in Canada, was sold under a licensing system, while the title to the land remained with the Government. The licence contained such provisions as were deemed necessary to assure the protection and renewal of the forest. Thus Canada received a substantial revenue from its timber, was able to exercise a measure of control over methods of cutting, and yet retained possession of the country's forest lands.

During most of the nineteenth century, the public domain continued to shrink through the unsound legislation of Congress and the ineffective administration of the Department of the Interior. In the late 1870's a few far-sighted people began to see the dangers which would follow the rapid devastation of the forests. Their efforts resulted in the setting up of a very small and inadequately financed Bureau of Forestry in the Department of Agriculture. It was a tiny seed but the forerunner of the present large and efficient U.S. Forest Service.

The turning point in the disposal of the public domain came in 1891 with the passage by Congress of a bill carrying an inconspicuous rider authorizing the President to withdraw from entry by proclamation parts of the public domain to form forest reserves. Successive Presidents were not slow to avail themselves of this authority, and proclaimed a number of forest reserves. But by this time nearly all of the best and most accessible timber lands had passed into private hands and the Government was left with only about one-fifth of the area of commercial forest still remaining in the country. After the Weeks Act of 1911, and the Clarke-McNary Act of 1924, lands in the east, mostly cut over, were purchased, to the extent eventually of about 20 million acres. The total area now in the national forests, exclusive of Alaska, is 180 million acres.

The year 1900 saw two important events in U.S. forestry. The Society of American Foresters, for professional foresters only, was started with six members. It now has over 11,000 and exerts a powerful influence by maintaining high professional standards and advancing the science and practice of forestry through its official publication, the *Journal of Forestry*, to which *Forest Science*, a quarterly, was added in 1955, as well as through the meetings of its sections and of the Society as a whole, which provide for the interchange of ideas and foster *esprit de corps*. The second event in 1900 was the opening of the School of Forestry at Yale University, the first in the United States with an uninterrupted existence. The

course was 2 years, open only to those already having a bachelor's degree, and leading to an M.F. Some years later doctor's degrees were granted. The first Dean, Henry S. Graves, like his close friend Gifford Pinchot, received his forestry training abroad. There are now 24 schools of forestry accredited by the Society of American Foresters, mostly with 4-year undergraduate courses, but some of them providing also graduate and doctor's degrees. The number turned out by all these schools in 1955 was 829 with bachelor's degrees, 199 with master's degrees, and 33 with doctor's degrees, a drop from the high point in 1950 when the figures were respectively 2,321, 275, and 29. Yet, though neither this nor the actual figures just given are mentioned in the book, there is a fear in some quarters that these numbers will soon be insufficient. The author, himself Dean Emeritus of one of the largest and oldest schools of forestry, points out the interesting fact that the forestry profession is unique in that the training of foresters started *before* there was a demand for their services.

Forestry came to public attention from 1905 to 1908 as it had never before and seldom has since. Gifford Pinchot became a close friend of President Theodore Roosevelt, who, like Pinchot, believed that forestry and the conservation of natural resources were the most important problems facing the American people. The President, a man of extraordinary force and energy, threw the whole weight of his high office behind Pinchot without stint. In 1905 Congress transferred the forest reserves, renamed national forests to show that they were open for use, from the inefficient (reviewer's adjective) administration of the Department of the Interior to the Division of Forestry, renamed the Forest Service, in the Department of Agriculture, where they have since remained in spite of occasional attempts by certain Secretaries of the Interior Department to get them back. Pinchot changed his title from Chief of Division to simply The Forester.

In 1908 President Roosevelt called the Governors of all the states to a conference at the White House in Washington to consider the conservation of natural resources. The conference had a strong effect on public opinion, and a number of the Governors set up organizations within their states to deal with forestry and other aspects of conservation.

Theodore Roosevelt's successor in the White House was a very different sort of man, without the slightest interest in Roosevelt's conservation policies which he had promised to continue. His Secretary of the Interior, Richard A. Ballinger, became involved in some mining claims in Alaska which the Interior Department's own investigator found to be fraudulent, and was sacked for his pains. Ballinger approved the claims. As they were on a national forest, Pinchot vigorously opposed them. When a Senator wrote Pinchot about the matter, he replied, after talking it over with the Secretary of Agriculture whose approval he, apparently mistakenly, thought he had. For this breach of the rule against writing to a member of Congress without the permission of the Secretary of his Department, the President summarily dismissed Pinchot. Congress investigated the affair in hearings which lasted 4 months, and were widely publicized over the whole country. Pinchot was vindicated, Ballinger was disgraced, and the President was humiliated for upholding Ballinger. Nobody was deceived by the com-

mittee's formal vote, on a strictly party basis, exonerating Ballinger, who, soon afterwards, resigned. One of the salutary effects of the conflict, though Dana does not mention it, as Alaska is outside the scope of his book, was to make the public determined that the resources of Alaska should not go the way of those in continental United States. After dismissing Pinchot, the President, greatly to his credit, appointed Henry S. Graves, Dean of the Yale School of Forestry, to be his successor. It is the reviewer's opinion that a better appointment could not possibly have been made, aside from the fact that it set the precedent, which has been followed so far, of having a professional forester at the head of the Forest Service.

The author does not need to tell his American readers that when the national forests were put under the administration of the Forest Service there was a vast amount to do, building fire lookouts, trails, roads, telephone lines, ranger stations, &c. besides making maps and estimates of the timber. Grazing had to be controlled because the national forests must not become subject to rights of user, which had grown to be such a burden in many European forests, a lesson Pinchot and Graves had learned in their European training.

During these years that the national forests were being developed, private forestry was making hardly any headway at all. An exception, for some inexplicable reason not brought out in the book, was the pulp and paper industry, of which some companies, mainly in the north-east, whose investments in plant, machinery, and power were so large that they could not afford to cut out and move on as the sawmills were doing, but had to protect their raw material supply. On the Pacific Coast the lumber industry was badly depressed by low prices, excessive mill capacity, and the heavy carrying charges—interest, taxes, and cost of fire protection—on large bodies of mature timber. Small wonder that the industry could not be induced to take any interest in forestry.

Meanwhile the range on the public domain, mostly semi-arid land impossible to farm without irrigation, was without control and seriously deteriorating from unchecked over-grazing. The Department of Agriculture, the logical agency to administer the range, was, in the reviewer's opinion, unable to overcome the hostility of the Interior Department, and, to prevent further damage to the range, stood aside. In 1934 Congress passed the Taylor Grazing Act, placing grazing administration on the public domain in the Interior Department. Grazing districts were set up, but are not very satisfactory from a public point of view because the stockmen have been given practically a vested interest in the range.

During the depression of the early thirties the National Recovery Act, in order to help the lumber industry, particularly on the Pacific Coast, allowed companies to form combinations contrary to the anti-trust law in return for cutting in such a way as to leave the forest in a productive condition. When the National Recovery Act was invalided by the Supreme Court as being unconstitutional, the owners decided that they would continue conservative cutting. As economic conditions improved, the larger owners adopted forestry methods, and now employ many professional foresters.

The controversy as to whether public regulation of private forests, which the

Society of American Foresters supported by a large majority, should be by the Federal government or by the States, has died down. Co-operation between the Forest Service and the states and private owners has been continued and strengthened. But there is no Federal regulation, and little or no support for it. A number of states, however, have passed laws regulating cutting on private forests, notably Oregon and Washington, the two states with the heaviest forests of Pacific Coast Douglas fir. There has been much progress in forestry in the pine forests of the south-east following the rapid expansion there of the pulp and paper industry.

The most difficult problem, as in other countries, is with the farmers and other small owners. In the United States the aggregate of these holdings include a large proportion of the total volume of commercial timber. Vigorous efforts are being made to educate these owners by every possible means, including free planting stock, advice, marking the trees to cut and marketing the timber, sometimes free and sometimes for a moderate charge.

The book is obviously designed as a textbook, and a very good one it is. There is a summary and brief list of references at the end of each chapter, and a summary chapter at the end of the book. The first appendix gives a survey of policy on wild life, soil, water, and minerals. A second appendix gives a chronological summary of important events in the development of colonial and federal policies relating to natural resources. A great advantage of the book is that it brings together in one place the laws (not their full text) and story of events scattered throughout numerous books and other publications, and gives a sound and penetrating analysis of all that took place. It is indeed an extremely interesting and valuable contribution to forestry literature.

REPORT ON THE MARKETING OF WOODLAND PRODUCE

We venture to draw attention to the *Report of the Committee on Marketing of Woodland Produce 1956* (The Watson Report) published by H.M.S.O. price 4*s*. 6*d*. net, and to the very important recommendations made therein.

We also draw attention to the Memorandum of Evidence submitted by the United Kingdom Forestry Committee to that Committee in 1954. This Memorandum has now been made available to the public by The Country Landowner' Association and, in a letter forwarding the Memorandum to members of the Association, the Chairman of the C.L.A. Forestry Sub-committee and of the U.K. Forestry Committee, Sir Richard Proby, says 'It remains to be seen to what extent woodland owners as a body judge the recommendations made in the Report of that Committee adequate to meet the situation. If you are a woodland owner and are interested in the future of private forestry, C.L.A. headquarters would be very glad in due course to receive your views, in particular as regards the recommendation for the formation of a new Woodland Owners' Association.'

THE SOCIETY IN PERTHSHIRE, 1956

I. THE EXCURSION

THE following has been compiled from notes received from Mr. E. H. M. Harris and from the note in handbook form supplied by the Forestry Commission.

Tuesday 25th September. The Atholl Estates were visited first, starting in the Warren Plantations composed of first generation hybrid larch, and moving northwards to Blair Atholl. On arrival at Blair Castle the party was welcomed by Mr. Iain Murray, and Mr. Hendry, the woods manager, gave an historical account of the woodlands and explained the management plan. Diana's Grove, a small wood of mixed north-west American and other conifers planted in 1880, was next visited. This contained some examples of tall trees measured in 1955 and including *Larix leptolepis*, 105 feet; *Abies magnifica*, 116 feet; *A. lowiana*, 134 feet; *A. concola*, 127 feet; and *A. grandis*, 138 feet. Also seen was a *Tsuga mertensiana* considered by some to be a natural spruce-hemlock hybrid. Thence to a number of larch plantations where thinnings were discussed and to the estate sawmill where a Pratchitt Pressure Plant using Celcure salts is kept for treating larch and other conifers for estate use and for sale.

The Forester Training School at Faskally was next visited. Here only the policy woods were seen. These woods consist of about 186 acres mixed broad-leaved and conifer. In view of the great variety of species, their excellent growth, and disproportionate age-class structure, it was felt that they should be managed on irregular lines appropriate for policy woods, and since 1954 they have been so managed under a plan drawn up by Professor Anderson who joined the party to explain the intentions of management. Briefly these are to bring the woodlands to a normal series gradually over a long conversion period of 120 years with a felling cycle of 6 years. Work in one block was seen. It is considered that the long conversion period is necessary to conserve the soil, but the incidence of *Fomes annosus* is so high that the period may have to be drastically shortened when the plan is revised at the end of two felling cycles in 1965.

Wednesday 26th September. After a brief stop at the Meikleour beech hedge, the party was welcomed at Rossie Priory by Lord Kinniard and shown a stand of mixed leaf-tree species managed by empirical methods by the owner himself. His aims are (i) the removal of unhealthy or defective trees, (ii) release of middle-sized trees and poles of the best form and vigour, and (iii) the removal of occasional old trees to create gaps for regeneration. The groups seen were mainly naturally regenerated groups of ash (*Fraxinus excelsior*), and sycamore (*Acer pseudoplatanus*) of various ages, but many other species occur including beech (*Fagus sylvatica*), *Quercus robur*, and wych elm (*Ulmus glabra*) and are encouraged on this fertile site. Good prices are obtained for the smaller sizes and the ash is used mainly for parts of farm implements and the sycamore for rollers for the Dundee jute mills. Conversion of the ash was seen at Messrs. Carr's sawmill where scythe sneds, hay rakes, and clothes pegs were shown. Rather surprisingly the rake handles are of pine imported from Norway.

At Balgowan Flooring Mill an interesting contrast between home-grown and imported timber was seen. Mr. Peter McAinsh the owner discussed the species used. Beech and oak have now largely given way to Nigerian hardwoods, particularly opepe (*Sarcocephalus*), sapele (*Entandrophragma*), and apa (*Afzelia* spp.). Many other species could be used, the requirements being wear, price, quality, availability, and size. The boards cut are air and kiln dried and then run into strips for use as high-quality flooring.

At Ledmore nursery, rain earlier in the afternoon made conditions for some of the machines difficult. The emphasis on mechanization was due to three factors: starting the nursery on dirty ground; the labour shortage in the area; and the Forester Mr. Rose's flair for devising machines. The machines demonstrated were the Inter-row and Alley cultivator, the Mounted Lining-out plough, and the Seed-Sowing and Grit-Distributing machines. The last was designed to experiment with the production of plants for the forest which are not lined out but merely undercut after sowing in drills at wide spacing.

At Murthly Estate only the two sample plots of *T. heterophylla* were seen. Measured in 1953 at the age of 47, main crop figures were as follows. Trees per acre, 537 and 298; average height of crop, 80 and 81 feet; breast height girth, 29·5 and 33 inches; volume per acre quarter girth, 7,538 and 5,100 cu. ft. A number of the trees are suffering from *Fomes annosus*.

Thursday 27th September. The day was spent in the famous Drummond Hill Forest, an area of 6,360 acres of which 4,100 acres are planted. The forest bears the imprint of the late William Ross who had been connected with the forest for some 34 years and much of what was seen was his work. The past reputation of Drummond Hill rested on the excellence of the European larch grown on it and this species was largely used for replanting. In the light of present knowledge, e.g. the incidence of *F. annosus*, it is probable that much of the drift soils on the north face would have been better planted with Norway spruce (*Picea abies*) and the drier part of the south face with Scots pine (*Pinus sylvestris*). The higher slopes carry Scots pine now. The high-fertility soils of the lower southern slopes carried broadleaved species with the former larch crop and it is the intention that this system should continue by retaining the best young larch, either singly or in groups, and fostering existing broadleaved species or planting broadleaved species together with small groups of fast-growing exotics.

Consideration was given during this walk to the future treatment of the large area of 32-year-old European larch typical of much of this species on the north face. Three possible solutions were suggested. Firstly, clear felling and replanting with a different species. This was thought to be poor silviculture and out of line with national policy. Secondly, heavy thinning to leave an open crop of larch which however would not fully utilize the site. Thirdly, thinning to about 70 stems per acre and underplanting with Norway spruce at 5 feet spacing, leaving good pockets of larch. This last solution found most favour, but there were obvious difficulties about putting it into practice.

Friday 28th September. In very heavy rain the party went to Kennel Bank, Dunkeld House estate, to see the European and Japanese larches. The Kennel Bank trees, the parents of the original hybrid larch, are the property of Messrs. James Jones & Sons, Timber Merchants and, while the characteristics of the trees are preserved in 'tree banks' notably at Newton seed orchard, we are none the less indebted to this firm for continuing to preserve the group intact. Their most valuable characteristics are good, straight growth and resistance to canker. A full account of the Japanese larch trees in the Avenue from which the hybrid seed was, and still is, collected will be found in the Forestry Commission's Forest Record No. 25 written by J. D. Matthews and reviewed by C. Syrach Larsen in *Forestry*, xxviii. 73–74. An account of the Hybrid larch *Larix* × *Eurolepis* Henry, by M. V. Edwards will be found in *Forestry*, xxix. 29–43.

Acknowledgement. The excursion was greatly enjoyed by all who took part though the weather was not as kind as in recent years. Thanks are due to all concerned for the excellent arrangements and hospitality. In particular to Mr. Oliver and Mr. Fergusson and other Forestry Commission staff and to the owners and staff of the Atholl Estates.

II. SHOULD WE MAKE WORKING PLANS?

(A report of the discussion held at Dunkeld on 27th September 1956)

The opening speaker, Professor Mobbs, supported the general use of working plans in forest management in Great Britain. In the older woodlands, for instance, they were needed in order to control fellings in relation to increment and to aim towards normality. In the newer forests, all still under 36 years of age, he was full of admiration for the work of creation, but not so much for the subsequent management. He could quote an instance where thinnings consisted in the removal of dominants, not as a matter of policy, but because there happened to be a demand for such sizes of timber! In these newer forests, where planting was still continuing, we need not at present worry too much about normality. Where planting was complete, however, we should have a succession of age classes within narrow limits and, particularly in cases where we were forced to adopt short rotations of 50 or 60 years, it was not too soon to begin to set our house in order and to get size classes better distributed, allowing for differences in quality.

He admitted the difficulty that often such essential matters as objects of management, length of rotation, and silvicultural treatment, were in doubt. We did not in fact know what to grow for, nor to what size. Whether to grow fast for bulk or more slowly for quality. He considered, however, that we could, in our plans, make reasonable guesses at all these. We could, for instance, indicate probable rotations, aiming a little high for safety and, above all, we could revise these plans frequently.

Working plans were needed and we should certainly make them. The proper person to make such plans was the professional forester. We did not get a blacksmith to remove our teeth.

Mr. J. A. B. Macdonald, after a brief imaginative frolic in the past in the course of which the writers of the ponderous Teutonic tomes on forest management and their disciples in the Indian Forest Service came in for criticism, settled down to say that the young Forestry Commission was very right to have little to do with old ideas of working plans, though in fact there had been a great amount of forethought and planning all along the line.

Had they accepted from the start control in the German manner, they would have built up a service of men who understood neither initiative nor original ideas. Even if modest working plans had been introduced, there would have been much wasted effort. Forecasts would have been made before site variations were recognized, before species' requirements were known, or growth rates had had time to express themselves. He agreed that many of the reasons for delaying the preparation of working plans had been removed by time, but he still believed that they were wise to 'gang warily' with working plans on anything like classical lines.

He was aware that there was criticism from the Universities but he considered that even there changes were becoming apparent, and that there was a move away from stark precision and from regimentation to a far more healthy interest in trees and why they grew or why they failed. He supported the long-established Forestry Commission system of close estimating, short- and longer-term planning and careful annual scrutiny and revision which went on both in the silvicultural and in the accounting sides. He distrusted any side-tracking of the essential duty of every forester, which was the promotion of sound silviculture.

He believed that it was a fair and he did not think a deadly criticism of the Forestry Commission, that little dictation on such matters as species or system had been given to its senior staff to date beyond the very widest encouragement to grow the best crops of trees. He thought that the time had arrived for a forecast of the pattern of larger forestry

enterprises in the future. There should be some quite general indication of policy as to the type of material which the Commissioners believed should be produced under certain widely different conditions.

We could give up crying for the moon, that was striving for the normal forest, but there was a real need to achieve a maximum amount of order and balance both as regards size or age classes and as regards output; and, under our conditions, size class was likely to be more controllable than age class. He was thinking not only of the present vast unbalance of age classes but also of the shocking irregularity of our ground types. He also had in mind the fact that the silviculturist could, by encouraging certain trees, produce quite useful big diameter-classes quickly, thus tending to smooth over the unbalance. Given good silviculturists in the field, he maintained that this could be effected by nothing more elaborate than a clear indication of policy from headquarters followed up by the type of check which the Forestry Commission already employed so fully.

It was, however, a fact that the Forestry Commission had working plans, or something that would function in their stead, very much in mind at that moment. He had been in the Commission for 34 years and still had faith in the good sense which underlay all their major decisions. He hoped and believed that any new system of control which was developed would cut right away from the cumbersome, stultifying, data-amassing working plan of old and that it would be an essentially live control whose life blood flowed from healthy forests and from the intense interest of a real live staff.

Mr. Hiley, who followed, said that the discussion on working plans had been devised 2 years ago when he was President of the Society. Now that he had handed over to Mr. Long, he could speak more freely. There was no need to be impartial or benign. He would, however, try to be wise.

He had tried to make a plan at Dartington but had failed because he did not know enough. In Great Britain *we did not yet know what we were trying to do.*

There was much to be learnt from South Africa. He was aware that those who had not seen Dr. Craib's plantations, did not like them—and had even been known to refer to them as Craib's orchards—but those who like himself had seen them, did like them. It was amazing how good they were.

But what did Craib do? He decided that they wanted trees quickly and that they could grow them to 18 inches in diameter b. h. in 30 years on good sites. Thinning schedules were therefore devised to produce this. The Forest Department considered how the resulting timber could best be sawn and, when he visited the mills, were favouring frame saws. Having got these basic points settled, they were in a position to prepare working plans.

Here too, in Great Britain, we must settle certain matters first before we can make effective plans. We must have a policy for the size of timber to grow and we must grow enough of that size. We must have the mills to saw it and must produce a graded article at a reasonable price. Until we did this, architects would continue to prescribe imported timber. We must have thinning schedules which would secure this. Hummel's thinning tables were of great value but not as guides to thinning. Timber which his thinning schedules would produce would be both bad and expensive.

Forestry in Great Britain was no longer the pleasant gentleman's occupation that it was when the Forestry schools started before the 1914 war. There was now a great need for speed. There was a need to reduce cost. You could work out the cost of growing a cubic foot of timber in various ways using the same data of costs of operations and prices of thinnings in each case. The relative costs of growing Norway spruce 12 inches q.g.b.h. was about 17*s.* per h. ft. with Wiedemann's 1st quality class, about 4*s.* 6*d.* with Hummel's 2nd quality class, and about 2*s.* 6*d.* with the same rate of growth but using a heavier, calculated, thinning grade.

Professor Mobbs had said that there must be objects of management and it was the job of the forestry schools to work out these objects *in terms of economics*. We must teach management as a marriage between silviculture and economics. Foresters should be taught how to build up a high productivity in value of timber, and this could best be secured by seeking a high 'financial yield'. That was how a higher standard of living was achieved. He appealed to the Forestry Commission to carry out the needed research and to the Universities to teach men to come into the woods to get productivity.

Dr. Hummel, who followed, announced the formation of a new management section in the Forestry Commission Research Branch of which he was to be in charge; he said that this would include posts for a forest economist and for a working plan officer. The management section would also assume some of the functions of the former mensuration section, including responsibility for the permanent sample plots and the census of woodlands. The basic data from these and other sources (e.g. timber trade statistics) would enable periodic 'appreciations of the situation' to be prepared in order to assist the Forestry Commissioners in formulating policy and adjusting it to changing conditions. For example, the types of produce we should aim at growing and the question of strategic and economic reserves of growing stock might have to be reconsidered from time to time. Among specific working plan problems, which were already being tackled by the section, was a study of methods for attaining normality. The most promising solution appeared to lie in a combination of several methods, i.e. the grouping of forests, planting up the best sites first, replacement of very poor woods, underplanting, stimulating the girth increment of selected stands by heavy thinning, and varying the rotation.[1]

The actual production of working plans would be left in the hands of the conservators and a revised code of procedure for Forestry Commission forests was at present being prepared by a small departmental committee which had already gone some way towards completing its difficult task.

He regarded management as the junior partner of silviculture; and mensuration as the servant of both. He disputed the contention that the thinnings given in the present yield tables were too light and instanced the sample plots of hybrid larch seen that very day. He regarded finance as important, but not paramount.

There had been, said Professor Champion, much criticism particularly by the earlier speakers, of working plans drawn up in the past. They had been described as old, classical, German, academic, Victorian, and rigid. He would submit that, though he made his first working plan in Germany and was a pupil of Schlich, he had always been opposed to rigidity in working plans. We must know what to do and the first purpose of a plan was to give direction and continuity in a forest. The plan must be simple and it must work. Periodic revision was most important. It was easy enough to revise a yield which was based on a good guess. In Europe the old ideas were changing, particularly in respect of giving priority over yield regulation to securing maximum production in all parts of the forest, and in paying more attention to the economic factors. It was perhaps significant that the first plan to contain money yield tables was Ray Bourne's plan written about 1914 for part of an Indian division. Turning to one particular aspect of Forestry Commission research that of thinning, he felt that the grades of experimental thinnings should have been extended further in the direction of heaviness beyond the probable optimum, i.e. that there should be thinnings in E and F grades. Dr. Hummel here intervened to say that the mistake was appreciated and that they were taking steps to correct it.

Others who took part in the debate included Messrs. McNeill, Maxwell Macdonald,

[1] We hope to be able to publish a paper on this subject by Dr. Hummel in a later number of *Forestry*.—Ed.

Ross, Major Brodie, Messrs. Cameron, Goodwin, Riddock, Garfitt, Smith, Blunt, and Gerald Palmer.

In closing the debate, the Chairman, Mr. Long, stated that he had felt bogged down by working plans all his life. He was, however, like everyone else in favour of them. They were indispensible in mature woodlands and particularly to private owners. As regards the young woods of the Forestry Commission, he did not feel that sufficient notice had been taken of the fact that they were in a state of evolution. They were, for instance, trying all sorts of new species and did not know what they were going to get from them. The demand and the requirements were changing. Imported timber was different from what it was. Substitution of steel for mining timber was increasing. There were increasing demands for pulp and for chipboards. Nor did he think that the timber trade really knew what was likely to happen. Yet in spite of this, we had long had the global plan of the White Paper; planting, thinning and other plans had developed in stages and now we had the new management section in the research branch. This was progress, and, when we had got a little farther still along the road, we would be better able to see more clearly.

III. PROPOSED ALTERATIONS IN THE CONSTITUTION AND RULES

The matter was discussed at the 29th Annual General Meeting held at Dunkeld on 27th September and at that meeting (1) a motion was put forward to amend Article VIII of the Constitution so that the levels of subscriptions could be fixed more readily by Rule and (2) a Committee was set up to draft other alterations felt necessary in the Constitution and Rules.

Formal intimation of (1) will be given in the notice calling the 30th Annual General Meeting and if the motion is carried at that meeting, the intention is to revise subscription rates by Rule as below with effect from 1st January 1958.

Fellows, Professional Associates who as such have already paid five annual subscriptions, and Ordinary Members . . . . . £2. 2s. 0d.

Professional Associates who as such have paid less than five annual subscriptions, and Professional Members . . . . . £1. 1s. 0d.

The alterations drafted by the Rules Committee under (2) have since been approved by the Council and aim principally at giving a larger say in the management of the Society to members other than Fellows and specifically to increase the proportion of members other than Fellows on the Council, to give to all members the right to vote at Annual General Meetings and the right to nominate office bearers and councillors. These proposals will be placed before the 30th Annual General Meeting in 1957 but will lie over for decision until the Annual General Meeting in 1958.

IV. PROPOSALS FOR THE 1957 MEETING

It was agreed at Dunkeld that the meeting in 1957 should be in East Anglia from 24th to 27th September. We understand that the following will be included in the programme. (1) Ryston Hall and Weasenham. (2) Thetford Chase for large-scale thinning; conversion; and utilization. (3) Control of *Fomes annosus*; beech under difficult conditions; fire protection; Santon Downham seed extraction plant. We understand too that the emphasis at the meeting will be on utilization and marketing and that this will be a principal subject for discussion.

REVIEWS

Economics of Plantations. By W. E. Hiley. Faber & Faber Ltd., London, 1956, pp. 216. 25*s.* net.

Review by H. G. Champion

IN this book, Mr. Hiley makes yet another important contribution to the study of the economics of forestry, a subject which already owes a very great debt to him and in which he is our leading exponent. As the title indicates, the focus this time is on the plantations, the creation and tending of which constitute by far the greatest demand on the time and attention of British foresters, whether concerned with State or privately owned land. This is, of course, in strong contrast with the approach in most continental countries where much of the original forest survives, even if only in a very altered form, and some approach to a full series of age classes exists—indeed, there is often an excess of the older age classes rather than the younger.

As his many friends all know, Mr. Hiley favours heavy thinnings from an early age and short rotations. We are now provided with a detailed exposition of the reasons which underlie and support his views. Few of us would have the temerity to challenge him on his own ground, particularly with regard to the laborious calculations involved, the results of which will save much time for all concerned for many a long day. I doubt if he expects everyone to adopt his techniques in full, but I think he can confidently count on serious consideration being given to the arguments he has so clearly set out, and on setting in motion a general advance to heavier thinnings and ultimately shorter rotations in the future. Why then, with the case admittedly convincingly put, may there be some hesitation and slowness in accepting it and acting on it? Mr. Hiley is of course very well aware of the types of criticism and objection likely to be made and meets many of them most effectively. For instance, heavier thinnings of the already very large area of young plantations will obviously throw a still greater amount and proportion of small material on a market which may appear inadequate even with the present intensity, and the increasing outturn from State plantations may swamp markets even when new industries are developed to absorb it.

Perhaps the aspect which will engender most questioning is the assumption that the trees will obligingly play the role assigned to them when they are expected to respond to a calculated thinning regime (p. 108). Craib's writings have familiarized most foresters with the idea that the competition for growing space may be at least as intense out of sight in the soil, as visibly in the crowns, and that trees may have greater powers of response to additional space than is reflected in past and current practices; also with the idea that it may be wrong to postpone thinning until the lack of room for the crowns is visibly reflected in their form. As against this, most are aware of the evidence of older work, that provided the canopy is more or less complete, the total current increment varies little or not at all with the number of stems, so that it is safer not to open too heavily with probable loss of increment for a period till the roots and crowns of the retained trees have grown enough to utilize the site to the full. Others are aware from experience that what they would describe as over heavy thinning will surely result in the development of a type of undergrowth which they associate with poor growth, and that when this is grass, as it often is, a very seriously enhanced risk of fire is unnecessarily introduced. All including Hiley and Craib agree that there will inevitably be much heavier branching which can

only be remedied by pruning and this may react unfavourably on increment, if it has to take living branches. In any case, even if the cost can be economically justified, pruning means one more job to find labour for and to supervise.

The reviewer is ready to accept Hiley's arguments for reasonably favourable conditions as regards rates of growth, labour, &c., but considers that the details have to be worked out for each species, site class, and other conditions as, indeed, Hiley himself admits, before one will be in a position to decide how far one can safely go in the direction suggested.

Much of the discussion is concerned with ring width and its effect on timber quality, the inadequacy of our present knowledge being freely admitted. We have but little precise knowledge and that little is somewhat contradictory, so that one is tempted to accept what fits one's views and pass lightly over the rest. Once again, the need of more research is evident as is set out in pp. 180–5. The reader will note that none of the three questions considered is biological on the grounds that this is a book on economics, not silviculture, but tree growth is so essentially a biological process that the economist keeping his eye only on the sawmill, costs and prices, may find he has left something vital out of the account. In this connexion we miss all reference to the work in this field by the wood anatomists.

There are many features of this book which merit complimentary mention. The familiar Faustmann formula can never have been so fully and lucidly explained with such a wealth of numerical demonstration of the effects of varying the different factors and of application to practical problems. The chapter on Costs is also very valuable, coming from an authority who has long experience and who has always made a special study of the subject. We must conclude as we began, by expressing gratitude and admiration of an outstanding piece of work. No one will be able to afford not to give most serious thought to the views presented whatever his present views and mental reservations.

The Structure of Wood. By F. W. Jane. A. & C. Black, London, 1956. Pp. 427. Price £3.

Review by L. Chalk

THIS book is stated to be intended primarily for the technical college student, without any previous knowledge of botany, working for a qualification in wood technology. As it describes the microscopic anatomy of wood and the fine structure of the cell wall in considerable detail and with many excellent illustrations, it should also be useful to forestry students. Other subjects included likely to appeal to a wider audience are figure and properties in relation to structure. The last third of the book is devoted to the identification of wood. The treatment here is original and is devoted primarily to showing by example how the features described earlier can be applied to identification. Keys down to generic level are given for eighteen common hardwoods (*Quercus*, *Ulmus*, &c.) and sixteen genera of the Gymnosperms. Keys for individual species are then given for 'Teak', 'Mahogany', and 'Walnut', these names being interpreted so widely as to include, for example, Merbau and Camphorwood as Teaks, Seraya and Makoré as Mahoganies, and Afara and Salix as Walnuts. Finally, one is taken back to the Oaks, Elms, and Ashes as examples of how far specific differences may be distinguished in the wood.

The anatomy of wood is spread over several chapters, and it is sometimes difficult, without resorting to the index, to know where to look for any particular feature. Apart from this criticism these chapters are well done and admirably illustrated, though there are some curious errors, particularly in the illustrations, which, it is hoped, may be corrected in future editions. For example, storeyed structure is illustrated by a *radial* section showing several vessel members that have obviously been cut off from the same cambial initial,

and the diagram illustrating Kribs's Ray Type III (for woods with uniseriate rays only) includes a multiseriate ray. The photograph illustrating 'latex canals' in *Alstonia* is misleading as it suggests that what are in fact radial 'latex traces' are longitudinal canals. The use of 'canals' instead of 'tubes' to describe such elements is to be regretted as it suggests that they are not elements, but intercellular cavities.

The chapter on 'The Ultimate Structure of Wood' written by Dr. K. Wilson, provides a very useful account of the fine structure of the wall as revealed by polarized light, X-rays, and the electron microscope. It is encouraging to find variation in wood stressed and the student made aware both that twigs and wood near the pith may differ from mature wood and that there may be considerable variation between specimens from different trees. The rest of this chapter is concerned mainly with reaction wood, followed by very brief accounts of fungal attack, brashness, and brittleheart. The treatment here is very uneven and it is to be noted that in the text no mention is made of the slip planes that are such a characteristic feature of the latter and the important associated defect known as a thunder-shake or natural compression failure receives only half a line. Both these features are, however, illustrated.

Figure in wood is always an attractive subject and the chapter on this is one of the best in the book. The author has quite frankly made up his own definition of what he means by figure, and does not clearly distinguish between figure and grain, but the features discussed and illustrated are much what one would expect. Another chapter that has an obvious appeal is that devoted to the properties and uses of wood in relation to its structure, but to the reviewer this is rather disappointing. Several minor points, such as why clogs should be made of alder, and why willow should be resilient, are discussed at length, whereas modern work on the effect of lignin, cell wall thickness, and ring width on different types of strength, the effect of wood structure on shrinkage, and on suitability for flooring and plywood receives bare mention or none at all.

Most of the criticisms made above are on the score of omission and it must be emphasized that such criticism has been made from the point of view of the interest of the book to a forester. The book is very well produced and the author is to be congratulated on the excellent illustrations.

CORRESPONDENCE

Society of American Foresters
Washington 6, D.C.
10th August, 1956

Dear Mr. Palmer

We in the Society of American Foresters are pleased that *Forestry* has given space to long reviews of two books that this Society produced in 1955. I refer to *Forestry Handbook* reviewed by W. E. Hiley and *Forestry and Related Research in North America* reviewed by H. L. Edlin, both in Volume XXIX, Number 2 (May 1956).

Mr. Hiley's criticisms of the *Handbook* are well taken. No one realizes better than I that certain additional data might have been included. The volume was 7 years in preparation. Actually, more than 200 technicians contributed to it in one form or another. And at times I almost despaired of its ever seeing the light of day. Material equal almost to one-quarter of the present book was deliberately not included, because the book would have been almost unmanageable.

The point is well made by Mr. Hiley that the book is almost too large to handle with comfort and it might have been better to make two volumes of it. Had we included the material omitted—material some of which Mr. Hiley has failed to find in it—we would have had two volumes, but priced out of the group of professional workers we wished most to aid, field foresters without libraries and other sources of reference handy.

The *Handbook* is priced at $15. Nearly 4,000 copies have sold. Admittedly, the price is high. But had we published two volumes or a total of 1,500 pages the price could conceivably have gone up to $20 or more, and it is questionable whether a commercial publisher would have brought it out or whether many foresters could have afforded to buy it. Doubtless Mr. Hiley, who has written some excellent books of his own, understands the compromises that frequently must be made between author and publisher if a work is ever to go on sale.

With respect to Mr. Edlin's review of *Forestry and Related Research in North America*, I admire his scholarly approach to the subject. He makes certain comments that we shall keep in mind as being helpful if the Society of American Foresters undertakes a similar study of forestry education, as we hope to do.

But Mr. Edlin makes one criticism which is difficult to understand in the light of the title and purpose of the book. He rebukes us because '. . . scarcely a word is said about any other country in the world'. He accuses American foresters of having 'developed an insular outlook on their subject matter; that they have little concern for the groundwork of forest science developed in Europe and Asia; and that most of them are unaware of its existence. We all know', he concludes, 'that North America is virtually self-sufficing in timber; here it is made to appear self-sufficient in science.'

Those are harsh words. Possibly they are deserved. I would defer to Mr. Edlin's judgement as to our insularity of outlook in forest science because he can doubtless see us more objectively than we can see ourselves.

But as to the book. Its stated purpose is to review the progress of forestry and related research in North America during the past quarter-century, and to formulate recommendations and goals for the next quarter-century. Now, to criticize it for failing to include mention of research progress throughout the world seems less than reasonable. If a book purports to be no more than what its title claims, is it not captious to fault it for not being something else?

Despite Mr. Edlin's implications to the contrary, American research workers try to keep abreast of world literature. Although we may not have mentioned *Unasylva* and *Forestry Abstracts* in the book, both are respected in America as mediums for the communication of research results.

To sum up, in behalf of the Society of American Foresters I thank you sincerely for the two analytical reviews. Both make points that should be helpful if the Society embarks on similar projects in the future. And I hope we shall.

Cordially yours,

HENRY CLEPPER
Executive Secretary

continued from inside front cover]

The membership is divided into four classes, the respective qualifications being as outlined below:

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